QUEENSLAND.

DEPARTMENT OF AGRICULTURE AND STOCK

DIVISION OF ENTOMOLOGY AND PLANT PATHOLOGY

Pests and Diseases of Queensland Fruits and Vegetables

. . By . .

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and

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Introductory Note.

Attention was recently directed to the desirability of preparing a comparatively brief summary of what is at present known with respect to some of the commoner pests and diseases of Queensland fruits and vegetables. This has been done, and the assembled information is now presented in handbook form. The entomological notes have been prepared by myself, while those dealing with plant pathology have been written by Mr. Simmonds.

The majority of the chapters in this handbook have been devoted to a discussion of some of the commoner pests and diseases, and these have been written in as simple a style as is practicable. Other chapters, such as those dealing with insects, insect anatomy, fungi and bacteria, are of a slightly more technical nature, but they have been included because it is believed that a knowledge of their contents will enable the grower to more intelligently and effectively set about the task of applying control measures.

The handbook thus serves a twofold purpose; firstly it briefly discusses the available information with respect to some of the commoner pests and diseases, and secondly it contains a short account of the rudiments of entomology and plant pathology.

Certain sections of the text have already appeared in the "Queensland Agricultural Journal," but by far the greater portion has been specially prepared for this publication.

The handbook is illustrated by a comprehensive series of black and white plates, colour plates, and photographs, and its usefulness is thereby very materially enhanced. A large number of the illustrations have been prepared by the Division's Illustrator, Mr. Helmsing, and the authors are also indebted to the Departmental Photographic Branch and to the Government Printer for valuable assistance in the matter of illustrations.

ROBERT VEITCH,
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Pests and Diseases of Queensland Fruits and Vegetables.

CHAPTER I.

INSECTS AND THEIR RELATIVES.

Insects belong to the extremely important group or phylum of the animal kingdom known as the Arthropoda. The great majority of described species of animals are included in that group, and its members occur in salt water, in fresh water, and on dry land. The group includes insects, lobsters, crayfish, crabs, shrimps, woodlice, centipedes, millipedes, scorpions, spiders, ticks, and mites.

Many of these small animals differ from each other very considerably in structure. There are, however, a number of fundamental characters in which they all agree, and a combination of several anatomical features, common to all the animals just mentioned, justifies their formation into one large group and also serves to separate the members of that group—i.e., the Arthropoda—from all other animals.

Even a casual examination of a typical Arthropod reveals some of these distinctive features. Perhaps the first point observed is the fact that the body consists of a series of segments or pieces each of which very frequently bears some degree of resemblance to its neighbours. These segments are placed one behind the other, and the division between any two is generally rather clearly marked in at least some portion of the body. The Arthropod body bears a variable number of paired jointed appendages, while a further typical feature is the chitinous external skeleton protecting the soft internal tissues of the body. Chitin is a somewhat horny substance secreted by certain layers of cells in the Arthropod body, and its presence in the cuticle, or outer skin, which it permeates, results in the production of the typical hard outer skeleton. The existence of this external skeleton accounts for the peculiarity that, after death, there is apparently no decay; decomposition of the internal tissues nevertheless does take place and eventually only an empty shell is left. This empty shell is, however, invaluable to the entomologist and zoologist for purposes of classification and identification. A further characteristic feature of this group of animals is

the fact that the body is bilaterally symmetrical—i.e., it is evenly developed on both sides.

A bilaterally symmetrical body bearing paired jointed appendages and composed of a series of segments with a chitinous outer skeleton may therefore be regarded as the main distinctive external features of the Arthropoda.

Having drawn attention to some of the more easily observed structural characters that serve to separate the Arthropoda from the rest of the animal kingdom, consideration may now be given to a brief preliminary outline of the anatomy, habits, and economic status of certain of the more important classes of the group.

Lobsters, Shrimps, Crabs, Crayfish, Prawns, and Woodlice.

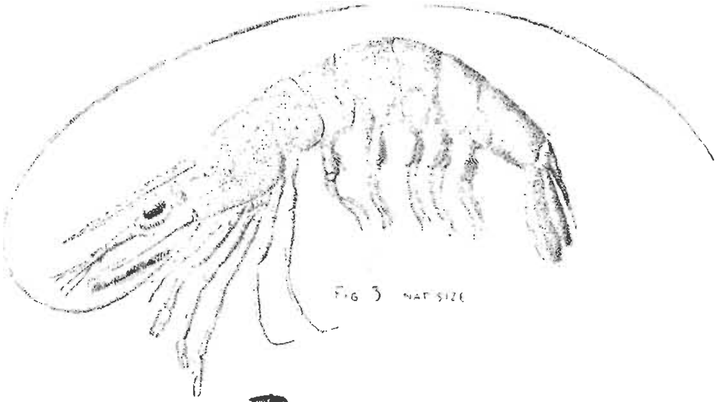
The Crustacea, the first class to which reference will be made, are represented by lobsters, shrimps, crabs (Plate 1, fig. 1), crayfish, prawns, and woodlice, and are almost entirely aquatic, being mainly marine. The woodlice (Plate 1, fig. 2) are, however, exceptions to these aquatic habits, being land forms commonly found in damp localities where they frequent the undersides of stones and boards and the damper clumps of heavy vegetation in gardens and fields. Decaying vegetation is generally regarded as the normal food of woodlice, but numerous instances have occurred where they have fed on the roots and foliage of small plants and also on edible mushrooms; they are thus of some slight economic importance. Some of the Crustacea—e.g., the crayfish and the prawn (Plate 1, fig. 3)—are of value as a source of food for man.

Crustacea are generally regarded as performing, in fresh and salt water, practically the same functions as those with which insects are associated on land—i.e., some are feeders on vegetable growths, some are predaceous on other animals, while many act as scavengers.

Many species of Crustacea breathe by means of gills, but respiration in the smaller species frequently takes place through the whole body surface. Two pairs of antennæ or "feelers" are present and the body is furnished with a variable number of pairs of jointed legs. The body segments in the higher Crustacea are grouped into two regions—namely, the cephalothorax or head-thorax and abdomen.

Centipedes.

The centipedes or Chilopoda, unlike the previous class, live on land, although a few abnormal species frequent the shore where they are regularly submerged by the tides. They are active fierce animals that are but little seen owing to their secretive habits; they may be frequently found, however, by turning over stones or heaps of leaves



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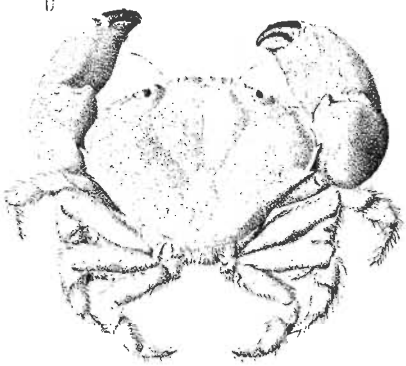

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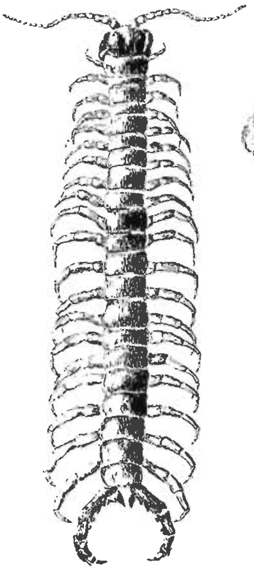

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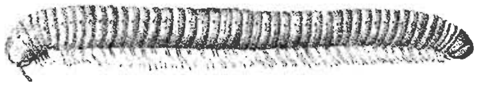

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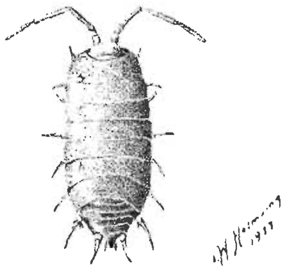


Fig 2 × 4

Plate 1.—Fig. 1, Crab; Fig. 2, Woodlouse; Fig. 3, Prawn; Fig. 4, Centipede; Fig. 5, Millipede.

or by tearing the bark off rotting trees and stumps. They cannot be regarded as being of any very appreciable economic importance, although in some cases they may be slightly beneficial by virtue of their habit of feeding on other small animals. Unfortunately, however, they are capable of inflicting an unpleasantly poisonous bite and are therefore not unnaturally regarded with considerable feelings of aversion.

The somewhat soft centipede body (Plate 1, fig. 4) consists of two sections only—namely, the head and trunk, the latter consisting of a series of practically identical segments, which in some species number well over a hundred. The whole body has a rather flattened appearance, and although most of the species are long and slender some are short and broad. A pair of many-jointed antennæ or "feelers" is present on the head, the minimum number of antennal joints being generally regarded as fourteen. Each typical body-ring or segment bears a pair of legs, the first pair being modified to form poison claws; large poison glands are situated at the base of the claws, the poison being conducted from the gland to the wound through a canal in the claw. Centipedes breathe by means of air tubes ramifying throughout the body tissue.

Millipedes.

The third class of which mention may be made is the Diplopoda or millipedes. These small animals in some respects closely resemble the centipedes, and, like them, they are inhabitants of the land and breathe by air tubes. The millipede head possesses a pair of seven-jointed antennæ and its body (Plate 1, fig. 5) consists of a series of segments which are all practically alike in appearance. The segments in this case are distinctly cylindrical and as a consequence the general appearance of the millipede is somewhat different from that of the broader, flattened centipede. The body segments in the millipede are somewhat imperfectly separated, and hence, with a few exceptions, each "segment" bears two pairs of legs; there is, however, still a good deal of obscurity and uncertainty with regard to this feature of millipede anatomy. There is no modification of legs to produce poison claws, but special glands exist for the production of a particularly offensive fluid. There is a high proportion of lime salts in the external skeleton of this class of Arthropod and its skeleton is much harder than is the case in the centipedes. As in the centipedes, the body is divided into two sections only, namely, head and trunk.

Millipedes are generally supposed to live on decaying vegetable matter, but some species have been recorded as attacking potato tubers and the roots of plants. They are, however, of but trifling economic importance and generally live up to their reputation as quite inoffensive creatures.

Spiders, Ticks, Mites, and Scorpions.

The fourth class to which reference must be made is of decidedly greater importance to mankind than the three just discussed in that it includes the spiders, ticks, mites, and scorpions; this class is known as the Arachnida.

The Arachnida are found almost exclusively on land, and characteristically possess four pairs of legs, but no antennæ. Generally the segments of the body are grouped into two sections—namely, the cephalothorax and abdomen. Respiration may be by air tubes, by lung books, or even through the surface of the body; the name lung book is derived from the fact that these respiratory organs are leaf-like in structure. Blood from all parts of the body is carried to the lung books, where it is purified and is then ready to be carried back to the various tissues and organs. Spiders possess the ordinary air tube system but are also supplied with lung books, while in the scorpions respiration is by means of four pairs of lung books; in the ticks and mites respiration is generally by the simple air tube system, although in some of the mites air tubes are absent. The class is a very diverse one, the differences in structure being almost as wide as in the Crustacea.

Most of the members of this class are predaceous or parasitic on other animals and some are of very great economic importance because of the part they play in transmitting serious animal diseases.

The scorpions (Plate 2, fig. 1) are nocturnal in habit and sometimes attain a length of as much as eight inches; they are predaceous on other animals, insects and spiders forming the most important source of their food supply. A poison sting is situated at the tip of the abdomen and is frequently used in paralysing the larger insects or other small animals on which the scorpions live.

The spiders (Plate 2, fig. 2) are well-known predatory enemies of insects, but as they do not discriminate between destructive and beneficial species their actual value to the farmer is somewhat difficult to assess. Many spiders lead a sedentary existence, trapping their prey by means of snares of silk spun from the silk glands. Others obtain their prey by chase.

The mites (Plate 2, fig. 3) are generally very small animals that sometimes occur in enormous numbers. Some species attack plants, e.g., the so-called red spider, others are animal parasites, while quite an appreciable number live in decaying organic matter. The ticks (Plate 2, fig. 4) are well-known stock pests that are frequently responsible for the transmission of very serious diseases.

Insects.

The fifth and last class to which reference must be made is the most important of the five discussed, and is known as the Hexapoda or insects.

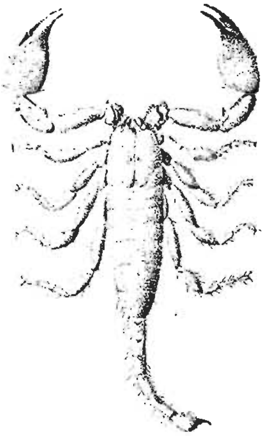


Fig 1 NAT SIZE

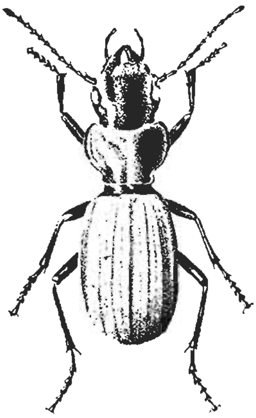


Fig 5 NAT SIZE

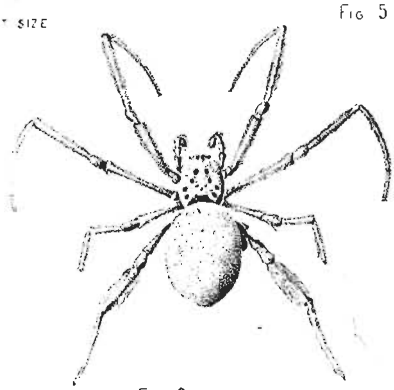


Fig 2 NAT SIZE

Fig 4 × 4

Fig 3 × 30

PLATE 2 —Fig. 1, Scorpion ; Fig. 2, Spider ; Fig. 3, Mite : Fig 4, Tick
Fig. 5, Insect.

The body segments in this class (Plate 2, fig. 5) are distinctly grouped into three sections—namely, head, thorax, and abdomen. The head almost invariably bears a pair of antennæ, while the thoracic or middle section of the body possesses three pairs of jointed legs and also bears two pairs of wings; the latter are very frequently closely folded on the abdomen when the insect is not in flight. Insects breathe by means of air tubes which radiate throughout the whole body.

Insects have shown wonderful powers of adaptation and they have succeeded eminently in the struggle for existence on land; so much so that, without being unduly pessimistic, it may be claimed that the future will witness a severe struggle between man and insect for the world's available food supply. The wonderful success of insect life on land has not, however, been repeated in either fresh water or in salt water; only a comparatively few species pass both the adult and larval stages of their life cycles in or on the former, while the number of marine insects is extremely small.

More than half a million species of insects are already known to science and some of the most destructive of these are steadily spreading throughout the world. The toll levied by some species is enormous, and what would otherwise have been profitable branches of agriculture have, in certain countries, been reduced to a state of stagnation owing to insect attacks, and they offer little or no inducement for further development. Other species are notorious as carriers of very virulent diseases of man and beast, and the settlement of some very fertile areas has been greatly impeded by the prevalence of these insect-transmitted diseases.

It is only recently that mankind has realised just how much his physical and material wellbeing depend on his ability to successfully combat these small but tremendously powerful enemies. The realisation of the seriousness of the position has led to markedly increased activity in economic entomological research throughout the world, and the results achieved in some investigations encourage the hope that in many of the other as yet unsolved problems success will lie with man in his fight against the insect world.

CHAPTER II.

INSECT ANATOMY.

As already indicated at the end of the preceding chapter, the body of an insect consists of three very distinct regions, each of which is composed of a number of segments. These three regions are the head, the thorax, and the abdomen, each of which can be clearly distinguished in such a common insect as the Queensland fruit fly (Plate 6, fig. 4). The main anatomical features and functions of these various regions will now be dealt with in some detail.

The antennæ, the eyes, and the mouth parts are the most conspicuous features on the insect head. They all perform highly important functions in insect life and, although certain impressions can be received by the insect through the agency of organs situated on different parts of the body, the impressions that are received by the organs situated on the head include the extremely important ones of sight, smell, touch, taste, and hearing.

The Antennæ.

The antennæ are a pair of very conspicuous jointed appendages situated on the head, either between or in front of the eyes. The shape and size of these antennæ vary tremendously in the different families of insects, but, although these variations are of great scientific importance, their discussion is unnecessary in these notes. It may be mentioned, however, that not only do striking differences occur in the structure of the antennæ of different insects, but they may also be found in the two sexes of the same species—e.g., in mosquitoes the antennæ are very plumose or feathered in the male, whereas in the female they are pilose or clothed with down.

Sense of Smell.

It is generally agreed that the olfactory sense or sense of smell is located mainly, but not necessarily exclusively, in the antennæ. Definite evidence exists to show that in certain insects the sense of smell is wholly restricted to the antennæ, and if these organs are removed the insects lose the olfactory sense. It must be pointed out, however, that in some other insects the removal of the antennæ does not appear to be accompanied by the loss of the sense of smell, a fact that seems to indicate that the olfactory sense in these particular species is not restricted to the antennæ. Nevertheless, it is probably correct to say that the sense of smell in the majority of insects is mainly, if not wholly, restricted to the antennæ.

The olfactory sense may perform several functions. It may enable an insect to find a suitable medium in which to place its eggs or maggots as in the case of the blow-flies. In these the sense of smell is extremely

acute and has been admirably developed for the purpose of enabling the flies to locate their maggots' food supply. A second function of the sense of smell is illustrated by the fact that it has been demonstrated that in certain moths the males find the females by virtue of the olfactory sense possessed by the antennæ; when these organs are removed the males are no longer able to find the females for mating purposes. Again, there is the relationship that exists between the sense of smell and the choice of food plants by female insects for the purpose of egg-laying or oviposition.

Perception of Sound.

The antennæ may also function for the perception of sound, a fact that is well illustrated in the case of mosquitoes. The antennæ of the male mosquito are very plumose, as a result of an extremely pronounced development of antennal hairs, and it has been experimentally demonstrated that these hairs may be set in vibration when certain tones are produced. It is argued that in this manner the male is able to locate the buzzing sound produced by the female, and so can fly to it for mating.

It must not be assumed, however, that the sense of hearing in insects is confined to the antennæ. On the contrary, auditory organs are also known to occur on other portions of the body, including the legs and abdomen.

Sense of Touch.

The sense of touch is also well developed in the insect world, and, as in the case of the auditory organs, it is by no means confined to one region of the body, although it is believed to be particularly well developed in certain portions, included amongst which are the antennæ. Apart from those areas in which the tactile sense is exceptionally well developed, practically any other part of the surface of the body possesses the sense of touch.

The Eyes.

The eyes in the insect world are of two distinct types—firstly, there are the large compound or faceted eyes; and secondly, there are the smaller simple eyes or ocelli. The compound eyes are clearly seen on each side of the head in such an insect as the Queensland fruit fly. An examination of these compound eyes by means of a hand lens will show that superficially they consist of an enormous number of very small areas or facets.

The number of facets in the compound eye is generally very large, being 4,000 in the case of the common house fly, as many as 25,000 in certain moths, while 28,000 has been recorded in some species of dragon flies. Exceptionally, there may be only a few facets, six to nine having been recorded in the worker caste of one species of ant.

The simple eyes are frequently absent in the adult insects, and in rare cases even the compound eyes may be missing. The simple eyes are generally the only organs of sight in immature forms of insects possessing a complete metamorphosis, such as caterpillars, but in internal parasites, such as wasp larvæ, even such simple organs of vision as definite ocelli are absent.

The discussion of insect eyes would be incomplete without a reference to the fact that frequently marked sexual differences occur in the eyes—e.g., in most flies the compound eyes in the male are appreciably larger than in the female.

Power of Vision.

With respect to the power of vision possessed by the two types of eyes just discussed, it is generally believed that through its compound eyes the insect is able to detect movements made by other animals or objects and also to recognise form. The power to detect movement probably extends to some considerable distance, but the perception of form is thought to be restricted to a few feet—probably six or seven. It is further believed that the simple eyes enable the insect to distinguish the form of objects in a crude manner, but such power is restricted to objects very close at hand. The simple eyes further enable the insect to distinguish light from darkness.

The Mouth Parts.

The mouth parts of many insects have undergone very profound modifications, and a number of distinct types of mouth may be observed even in the course of a very casual examination of some of the commoner insects. These varying types of mouth parts belong to the four following classes:—

(1) Biting and chewing mouths.

(2) Piercing and sucking mouths.

(3) Biting and sucking mouths.

(4) Sucking mouths.

Each of these common types of mouth parts is worthy of discussion.

Biting and Chewing Mouth.

The biting and chewing type of mouth is well represented by the grasshoppers and beetles. These insects feed by biting off and swallowing the tissue of the plants on which they live. The mouth parts have been modified to permit of this type of feeding, and the damage caused by these insects when attacking foliage or other tissue is usually very obvious.

Piercing and Sucking Mouth.

The piercing and sucking type of mouth is that possessed by scale insects, orange bugs, mosquitoes, and many other species of outstanding importance. In these insects the mouth has been so modified that certain

parts thereof known as stylets function for the piercing of the skin, cuticle, or epidermis. Through the wound thus made, the insect sucks out the blood or sap of its host animal or plant. The results of attacks by insects belonging to this class are not generally quite so obvious as in the case of those possessing biting and chewing mouth parts. Most people are aware, however, of the painful impression left by the attacks of sand flies and mosquitoes, and they also very frequently see leaves or young twigs of trees that have curled up and withered as a result of the attacks of aphids or plant lice. When plants are severely attacked by these insects the drain on their sap is frequently tremendous and the plants are consequently stunted and sickly, and, in fact, they not infrequently succumb to the attack in cases where the insects feeding on them are abnormally abundant. The importance of insects possessing this type of mouth is further demonstrated by reference to the fact that mosquitoes are responsible for the transmission of several very serious diseases of human beings.

Biting and Sucking Mouth.

The biting and sucking type of mouth is one that is found in the Hymenoptera, the order to which the bees and wasps belong. In this type the mandibles are well developed for biting, but at the same time other parts of the mouth are so modified that the insect is also able to suck up liquid food. Insects belonging to the other three classes possess mouth parts that can either bite or suck, but this is the only class in which both these modes of feeding can be adopted.

Sucking Mouth.

The last type of mouth part to which reference has to be made is that of the sucking type possessed by butterflies and moths. The mandibles in most of the moths and butterflies are absent, and other parts of the mouth have been modified so as to produce a long sucking tube through which liquids can be sucked up. Insects possessing this type of mouth are generally quite incapable of destroying plant tissue—i.e., when they are adults. Of course, moths in their immature forms as caterpillars possess a totally different type of mouth and they are, in that stage of their life history, able to cause very serious losses. It has been said that moths are incapable of injuring plant tissue and that statement in general is quite sound. There are, however, some exceptions, including the orange-piercing moths which are referred to in the chapter dealing with citrus pests.

The Thorax.

The thorax is the second or middle region of the insect body. It consists of three segments, and typically bears two pairs of wings and three pairs of segmented legs in the adult stage. The second pair of

wings in the flies, however, is represented by two small knobs known as halteres or balancers. Further exceptions occur in some families in which both pairs of wings are missing or rudimentary, sometimes in both and sometimes in one sex only. In other abnormal cases the wings may be restricted to a single pair in one sex only.

The Wings.

The first pair of wings is always situated on the middle segment of the thorax, the second pair being on the hind segment. When an insect possesses only a single pair of wings it is almost invariably the second pair that is absent. It has also been demonstrated that in some wingless insects (such as the flea) the wings have degenerated through lack of use, but in certain very primitive insects no trace of wings can be found even in the embryo.

The wings in many species such as the bees, wasps, dragon-flies, and flies are generally quite clear and membranous. This is, however, by no means always so, for in the grasshoppers and their allies the front wings are distinctly leathery, while in the beetles they are typically hard and horny. Again, in the moths and butterflies, both pairs of wings are generally densely clad with scales which frequently give rise to extremely beautiful wing patterns. It is thus evident that the wings of insects are subject to very great variation.

Very powerful muscles, whose function it is to operate the wings, are situated within the external skeleton of the thorax. These may drive the flight organs at the rate of 330 strokes per second, as is the case with the house fly; or on the other hand they may produce the much slower rate of vibration that is typical of many common butterflies, only nine strokes per second having been recorded in certain species.

The Legs.

The insect leg consists typically of five segments, the last of which is normally composed of five parts of varying size. This terminal segment of the leg usually bears two claws and is also frequently furnished with a pulvillus or pad. The pad is typically adhesive and is generally held to be responsible for the power that flies and other insects possess of being able to walk on ceilings and on the undersides of leaves, &c., in an inverted position.

Legs occur in the great majority of adult insects, but in their immature stages legs are by no means invariably present—e.g., many beetle larvæ and most hymenopterous larvæ are legless, and the legless condition is the rule in the larvæ of flies.

The legs function primarily for walking or running, but they are frequently modified for other purposes—e.g., in certain species the fore legs have been so altered in structure as to be suitable for burrowing,

while in some species they have been adapted for seizing other insects. The hind legs in certain species have been abnormally developed so as to permit of jumping or leaping for considerable distances.

The Abdomen.

The abdomen, which constitutes the third region of the body, consists of a series of segments that exhibit comparatively little variation. Perhaps the most conspicuous external features of the abdomen are those associated with reproduction, for in the female of many species an ovipositor or egg-laying tube is distinctly visible.

Respiration.

Respiration in the insect world takes place through a system of air tubes or tracheæ which ramify throughout the whole of the body and in this way carry oxygen to the various tissues and organs. The openings in the body wall which permit of air entering the tracheæ are known as spiracles or stigmata. These occur in pairs on the thorax and abdomen and are generally situated laterally. Special provision for respiration is made in the case of the larvæ of aquatic insects, the special organs developed to meet the unusual conditions being known as gills.

Reproduction.

The normal procedure of sexual intercourse is generally necessary for reproduction in insects, and the sexual act is typically followed by the laying of fertilised eggs. To this generalisation there are, however, quite a number of exceptions, for many insects are viviparous—i.e., the females do not lay eggs but give birth to living larvæ or nymphs. The eggs are produced within the body of the female, but they are retained therein until the incubation period has been completed and the maggots or nymphs that have hatched are then extruded by the female. Many aphids and scale insects are viviparous, as also are many species of flies.

A further point worthy of note in connection with insect reproduction is the fact that occasionally reproduction can take place without sexual intercourse. This phenomenon is known as parthenogenesis.

CHAPTER III.

INSECTICIDES.

The preceding chapter might be regarded by some readers as being of interest rather than of practical importance to growers. Such, however, is not really the case, for many points dealt with therein have an important bearing on the measures that may be adopted in combating insect pests, e.g. the varying structure of the mouth parts. The present chapter is, however, severely practical for it deals with the all-important subject of insecticides.

Insecticides are chemicals used in the control of insect pests. Their function is to kill the insect to be controlled without, at the same time, causing any appreciable degree of injury to the plant or animal host on which it is feeding or without injurious effect on the medium in which it may be feeding or breeding. Further important considerations in the choice of a chemical as suitable for insecticidal purposes are—firstly, its cost and method of application, which must be such that its use is economically sound and practicable; and secondly, its safety, in that it must be capable of being employed without danger to the operator when reasonable precautions are observed in its application.

The chemicals used as insecticides may be classified in three groups—firstly, stomach poisons; secondly, contact insecticides; and thirdly, fumigants. The choice of the particular class of insecticide to be employed in combating an insect epidemic will be determined partly by the conditions under which the pest is operating and partly by the feeding habits of the insect to be controlled.

Stomach Poisons.

As has already been pointed out in an earlier chapter many insects injure their host plants by actually biting off and swallowing portions of the foliage, fruit, or stalk of the plants on which they are feeding. Typical insects in that category are the army worm, the codling moth, the corn-ear worm, the cutworm, the fig beetle, the leaf-eating ladybird, and the pumpkin beetle.

The first four insects just mentioned pass through larval stages possessing chewing mouth parts which enable them to nibble off portions of the foliage, fruit, or stem of the attacked plants. The other three insects referred to possess chewing mouth parts, both as larvæ and beetles, and hence are destructive in two of their four life cycle stages, whereas the others are destructive in one only, the moths being incapable of injuring any part of the plant.

Spraying or dusting their food plants with poison is the control measure generally employed in combating the type of insect now under discussion. Some of the species, however, are more effectively controlled by the use of baits containing suitable poisons. On swallowing a certain amount of the poisoned food or bait, death rapidly ensues. For obvious reasons the materials used in this manner are referred to very appropriately as stomach poisons.

The insecticides belonging to this class are nearly all some form of arsenic which must conform to two conditions—firstly, it must be practically insoluble when made up into a spraying mixture, otherwise serious burning of the sprayed foliage will ensue; and secondly, it must be soluble in the digestive juices of the stomach so that it may be absorbed with fatal results to the insect that has fed on the poisoned plants or baits. When the insecticide is employed in the preparation *of a poison bait only the second condition need be taken into consideration.*

Arsenate of lead, Paris green and poison baits containing Paris green are later discussed in detail as being the most effective and most commonly employed representatives of this type of insecticide.

Contact Insecticides.

The earlier discussion of insect-feeding habits also showed that although many insects injured their host plants by chewing the foliage, fruit, or stem, another very important group was responsible for damage by piercing the epidermis or skin of the attacked plants and by extracting the plant sap through the punctures which they had made by means of their piercing mouth parts. In this class of insect the mouth parts are so developed that they are quite incapable of chewing, and their feeding is restricted to sucking plant sap just as a mosquito sucks the blood of humans. When the feeding habits of these sucking insects are considered, it is evident that it would be useless to attempt their control by arsenical sprays spread over the surface of their food plants. The surface tissue is never eaten by this type of insect and hence the poison would not be swallowed.

Stomach sprays of the arsenical type being impracticable for sucking insects assistance must be obtained from another class of insecticide, and it has been found that what are known as contact insecticides are very effective for the control of these sucking insects.

Contact insecticides owe their killing properties to a number of factors. The mortality produced by their application may be due to their corroding influence on the bodies of the insects covered by the contact sprays. They may suffocate the insect by the closure of the pores through which it breathes or, on the other hand, death may ensue as a result of the more volatile portions of the insecticide passing in through the breathing pores of the body.

Insects against which contact insecticides may be employed are well represented by the scale insects and aphids.

Kerosene emulsion, resin wash, miscible oils, nicotine sulphate, and lime sulphur are later dealt with in some detail as typical representatives of contact insecticides.

Fumigants.

Reference must now be made to the third class of insecticide—namely, fumigants. Fumigants may be employed against both the chewing and sucking type of insect, but difficulties are frequently encountered in their use and generally, but not invariably, they are employed only in enclosed spaces. Fumigants produce gases which kill by entering the breathing pores of the insect body and destroying the tissues or by suffocation following on the removal of oxygen.

The fumigants most commonly employed in Queensland are hydrocyanic acid gas and carbon bisulphide; detailed discussion of fumigants will be confined to these two insecticides.

Arsenate of Lead.

Arsenate of lead is without doubt the most suitable and the most popular form in which to use arsenic as a stomach poison on insect infested foliage. When mixed for spraying it settles slowly in the mixture and it adheres longer to the foliage than other stomach poisons such as Paris green. Further points in its favour are the fact that it does not at all readily burn the foliage, and its presence can easily be detected on the leaves, thus enabling the operator to make sure that the spraying has been complete and effective. It does not kill so quickly as Paris green, but is much safer to use on foliage.

Arsenate of lead may be bought either in powder or paste form. When the powder is used in the preparation of a spray it is essential that every particle should be well moistened before the arsenate of lead is added to the water. A thin paste, free from lumps, is therefore prepared by gradually adding small quantities of water to the powder until it is thoroughly wet. The paste prepared in the manner just described is then poured into the vessel holding the rest of the water to be used in the preparation of the spray.

Various formulæ are in use for arsenate of lead sprays, but one that has given satisfaction as a standard spray is—

Arsenate of lead powder	1½ lb.
Water	50 gallons.

If the paste form of arsenate of lead is used the formula must be modified as follows:—

Arsenate of lead paste	3 lb.
Water	50 gallons.

Arsenate of lead is also frequently used as a dust instead of a spray, hydrated lime being generally employed as the carrier. Formulæ for

the arsenate of lead dust vary from one part of arsenate of lead to ten parts of hydrated lime to as high a strength as one part of arsenate of lead to three parts of hydrated lime. Mention may be made of the fact that quite a number of proprietary dusts containing arsenate of lead are at present on the market.

Paris Green.

Paris green is much less popular as a spray than arsenate of lead, its lack of popularity being due to a number of factors. Firstly, it settles much more quickly in the spraying mixture than is the case with arsenate of lead, and hence it is difficult to maintain anything like a uniform strength of spray throughout the operation. Secondly, it does not adhere so well to treated foliage and consequently must be applied at more frequent intervals to ensure protection. Thirdly, it is not so safe to use owing to the fact that Paris green may contain an appreciable percentage of water soluble arsenic and such soluble arsenic will burn foliage. That difficulty, however, may usually be overcome by the addition of lime. The added lime combines with the soluble arsenic and reduces the danger of burning the sprayed foliage. Paris green possesses the advantage over arsenate of lead in the rapidity of its effect on insect life.

Paris green used as a spray should be prepared in accordance with the following formula:—

Paris green	$\frac{1}{3}$	lb.
Quicklime	1	lb.
Water	50	gallons.

The Paris green should be worked up into a paste by the addition of a small quantity of water; then the lime should be slacked in a little water and added to the rest of the water. Finally the Paris green paste, which should be free from lumps, is added.

As in the case of arsenate of lead, Paris green may be applied as a dust, hydrated lime again being the ordinary carrier. Various formulæ show Paris green being used in the proportion of one part of the poison to from six to ten parts of the hydrated lime.

Poison Bran Baits.

Paris green has been referred to as presenting several unsatisfactory features when used as a spray, but in the preparation of poison bran baits employed in the control of such pests as cutworms it gives very good results. The danger of burning foliage no longer operates, and its relatively quick-killing powers render it more effective than arsenate of lead. A further attractive feature of Paris green is the greenish tinge imparted to the bait, thus enabling the operator to determine whether or not the poison has been thoroughly and uniformly incorporated in the bran.

Poison baits may be prepared in accordance with the following formula :—

Bran	25 lb.
Paris green	1 lb.
Molasses	1 quart.
Oranges	2 fruits.
Water	2 gallons (about).

The Paris green and bran should first of all be mixed together in a thorough manner and while still dry. The molasses and the finely chopped fruit and its juice should then be added to some of the water. The water containing the molasses should next be mixed with the bran and Paris green and the whole should then be well stirred up, enough water being added to produce the right consistency.

It is highly desirable that the poison bait should be of the right consistency, and only sufficient water should be added to permit of it being in a crumbly state and thus capable of being easily scattered broadcast on the ground. It should, at the same time, be sufficiently moist to permit of each flake of bran taking up its quota of Paris green and molasses.

Neither the fruit juice nor the molasses is essential in this bait, although they are usually considered desirable. Horsedung and sawdust have been substituted for the bran in certain formulæ, and smaller percentages of Paris green have also been used, but it is desirable to adhere to the formula given until such time as experiments have demonstrated the equal efficiency of cheaper formulæ when used in this State.

It should hardly be necessary to add that poultry and other domestic animals should not have access to areas that have been treated with poison bran baits.

Kerosene Emulsion.

Kerosene emulsion is one of the oldest insecticides employed against aphids and scale insects, but its use is now less general than was formerly the case. It possesses, however, one considerable advantage in the fact that all the ingredients required for its preparation can be readily obtained in any centre.

A common formula for the stock solution is as follows :—

Hard soap	½ lb.
Water	1 gallon
Kerosene	2 gallons

The soap should first be dissolved in the water by boiling and, while the water is still hot, the kerosene should be added to it, but not in proximity to the fire. This mixture should be churned up violently by means of a small spray pump for about five or ten minutes. A good

emulsion without trace of free oil should then be available. It is essential that the oil should be thoroughly emulsified because, if free oil is present, burning of the foliage may ensue. Soft water or rain water should be used in the preparation of kerosene emulsion, but if only very hard water is available it can be broken with lye. The stock solution prepared in the manner just described will keep for some considerable time, but some authorities maintain that it is preferable to prepare fresh quantities as required.

When required for use, the stock solution should be diluted by the addition of water. The proportion of water added will depend on the nature of the insect to be controlled, and also on the sensitiveness of the plant to be sprayed. Some authorities maintain that one part of the stock solution to fifteen parts of water is the highest strength at which foliage should be sprayed, while other investigators recommend a strength of one part of stock solution to ten parts of water and even less.

Mention has been made of the necessity of having the oil thoroughly emulsified to avoid the danger of burning the foliage. Attention has also to be directed to the fact that if much emulsion runs down the trunk of sprayed trees serious injury may be caused at or below the ground level. This danger may be avoided to some extent by building up a cone of loose earth at the base of the tree to be sprayed. Such a cone, 9 to 12 inches high and about 12 inches wide, will absorb an appreciable proportion of the surplus kerosene emulsion that runs down the trunk of the tree. After the tree has been sprayed the earth cone should be scraped away and, if necessary, the unsprayed portion of the trunk should be given a light spraying.

Resin Wash.

Resin wash is a spray that has enjoyed a considerable amount of popularity when employed against scale insects attacking citrus trees.

A formula recommended in New South Wales is as follows:—

Caustic soda, 98 per cent. quality ..	5 lb.
Resin	16 lb.
Soft soap	6 lb.
Water	100 gallons

The wash is prepared by boiling 10 gallons of water and adding to it the finely powdered resin, caustic soda, and soft soap. The mixture should then be boiled for two or three hours. It should be frequently stirred and small quantities of hot water added from time to time until there is 20 gallons of the mixture. Hot water is used in diluting the mixture, 1 gallon of the mixture being used to 4 gallons of hot water.

Resin wash has its maximum efficiency as a spray when the young scales are hatching out. It should not be used when the trees are suffering from the effects of a dry spell.

Like kerosene emulsion, resin wash is now less used than formerly, and it has largely been supplanted by other sprays and by cyaniding.

Miscible Oils.

Miscible oils are mineral oils that have been treated in such a manner that they will mix quite freely with water. They have been extensively used during recent years as sprays for the control of scale insects.

Quite a number of proprietary brands of miscible oils are on the market and, as a rule, full instructions as to the mode of mixing and application are issued by the manufacturers. It is essential that these oils should emulsify properly, and that they should not be used at too great a strength, otherwise injury may result to the treated plants.

Nicotine Sulphate.

Nicotine sulphate is a spray that is enjoying a very considerable degree of popularity as a suitable insecticide against aphis, thrips, and other small and delicate insects. It is marketed as a highly concentrated tobacco extract, in which 40 per cent. of nicotine occurs in the form of nicotine sulphate.

This insecticide is generally used at a strength of one part of nicotine sulphate to eight hundred parts of water, a common formula being—

Nicotine sulphate, 40 per cent.	½ pint
Soap	2 lb.
Water	50 gallons

The soap is added to produce a better spread and adherence of the spray.

Nicotine sulphate is also often applied as a dust, hydrated lime being in many cases employed as the carrier. The proportions in this dust are generally 5 lb. of the nicotine sulphate to 95 lb. of the hydrated lime. Various proprietary dusts containing nicotine sulphate are now on the market.

Lime Sulphur.

Lime sulphur is one of the most important sprays used as an insecticide, and it possesses the further merit that it is also a valuable fungicide. It was formerly made on the orchard by boiling a mixture consisting of sulphur, lime, and water. The concentrated lime sulphur solution, however, is now manufactured commercially, and is largely used in place of the home-made article, the preparation of which is a decidedly unpleasant task. Home-made lime sulphur is further referred to in Chapter VI.

The concentrated solution must be diluted before being used as a spray, and in order to determine the exact amount of dilution necessary

a Baumé hydrometer is used. This is necessitated by the fact that the strength of the concentrated solution varies quite considerably. The hydrometer is placed in the solution, and the number of degrees registered by it is noted. The reading on the hydrometer indicates the specific gravity of the solution, and by comparison with a table the necessary amount of dilution will be shown.

Carbon Bisulphide.

Carbon bisulphide is a liquid that evaporates very rapidly on exposure to the air, forming a heavy, highly explosive and inflammable gas. It should, therefore, not be brought into contact with a flame or highly heated pipes, and it is just as well not to smoke when using this fumigant. Although it does not possess the extremely dangerous properties of hydrocyanic acid gas, carbon bisulphide should, nevertheless, be treated with great respect, and the operator should, as far as is practicable to do so, avoid inhaling the vapour.

Carbon bisulphide is used principally for the fumigation of stored seeds that may be insect-infested, and it is also frequently employed in the destruction of ants' nests. It is a highly efficient fumigant for the purposes to which it is usually put.

It is generally considered that at least moderate temperatures are required to permit of satisfactory results being obtained in carbon bisulphide fumigation. Less than 60 deg. Fahr. has frequently been productive of very disappointing results, and a temperature of 70 deg. Fahr. or more is desirable.

When carbon bisulphide is used for the fumigation of seed a suitable container must be selected, and care should be taken to ensure that it is quite as airtight as is practicable. The seed to be treated is placed in the container and the fumigant is then added. As the gas produced by the evaporation of the liquid is much heavier than air, it is usual to place the carbon bisulphide in saucers or other vessels on the top of the material to be fumigated, so that the heavy vapour will be diffused through the whole of the enclosed space. As soon as the carbon bisulphide has been placed in the saucers, the container, whether it be a small box or a large iron tank, should be immediately tightly closed.

It has been demonstrated that under average conditions 4 to 5 lb. of carbon bisulphide per 1,000 cubic feet of container will produce satisfactory results in a reasonably airtight container if the insect-infested seeds are exposed to that concentration of fumigant for a period of about thirty-six hours. At the conclusion of the fumigation period the treated seeds or grain should be ventilated or aired.

It is well to remember that this fumigation will kill only the insects that are actually living in the seeds at the time of treatment.

To ensure continued freedom from attack the fumigated seed should be subsequently stored in containers that are free from insect infestation, and are so constructed that they can be satisfactorily sealed up.

Hydrocyanic Acid Gas.

Hydrocyanic acid gas is quite the deadliest chemical in general use as a fumigant in insecticidal work. It has been largely employed in the fumigation of buildings, imported raw materials such as cotton, dormant nursery stock, and last but not least in the treatment of scale insect-infested citrus trees. The following detailed consideration of hydrocyanic acid gas as a fumigant will be confined entirely to its use for the last-mentioned purpose.

The citrus trees to be fumigated are covered by sheets or tents in order to confine the gas for a sufficiently long period to permit of the insects being killed. The sheets used should obviously be made from a reasonably gas-tight material, and for this purpose an 8-oz. special army duck is employed as being most suitable. It is a common practice to dip the new material in a tannin bath in order to minimise the chance of mildew and rotting. The size of sheets or tents employed will, of course, depend on the size of the trees to be treated.

The hydrocyanic acid gas required for the fumigation may be generated in any one of several different ways. Originally potassium cyanide, sulphuric acid, and water were used for its production, but in recent years sodium cyanide has largely replaced potassium cyanide in the pot method of generating the gas. A more recent development in California has been the use of liquid hydrocyanic acid gas. Other developments have been the use of a dust known as calcium cyanide, while a fumigant called Zyklon has also appeared on the market as a source of hydrocyanic acid gas.

The procedure adopted when the pot system of fumigation is employed is briefly as follows:—The tree to be fumigated is covered by a sheet or tent of appropriate size and the number of cubic feet represented by the space enclosed by the sheet is ascertained by reference to a table. This figure on the table indicates in other columns the quantities of sodium cyanide or potassium cyanide, sulphuric acid and water required to produce the correct amount of gas to fumigate such a space. The necessary quantities of these materials are then accurately weighed out or measured, and the requisite amount of water is first poured into an earthenware pot or dish. The measured quantity of sulphuric acid is then added slowly and carefully to the water. Great care must be exercised in adding the sulphuric acid, because if it splashes on the body of the operator it will inflict severe burns. The earthenware pot is placed under the sheet or tent at such a distance from the side

of the sheet as to reduce to a minimum the danger of injury thereto by the splashing of the acid. As soon as the earthenware pot is in position the cyanide is dropped into it and a piece of sacking is placed over the pot.

It is essential that the cyanide should be added as soon as possible after the addition of the sulphuric acid to the water in order to obtain the best reaction. As soon as the cyanide has been dropped into the mixture of water and sulphuric acid that portion of the base of the sheet that has been raised to permit of the charging must be closed. It must be clearly understood that the hydrocyanic acid gas is generated very rapidly and is extremely dangerous, and hence the operator should on no account inhale it, and he should withdraw immediately the cyanide has been dropped into the pot containing the mixture of sulphuric acid and water.

In citrus fumigation the time of exposure of each tree to the gas is generally forty-five minutes, which is considered a sufficiently long period to permit of satisfactory results being obtained.

Fumigation with the pot system of cyaniding should be carried out at night, because then the danger of injury to the treated trees is materially reduced. It should never be done during the heat of the day nor in strong windy weather, and it is always well to exercise special precautions in fumigating weak trees. It is further desirable to make sure that the foliage and fruit on the trees to be treated are dry, and it is also generally advisable to avoid fumigating when a heavy dew is experienced. Fumigation of trees bearing an excessively large quantity of tender young growth may be attended with injurious results. A further precaution to be observed in connection with fumigation is that trees that have been sprayed with Bordeaux mixture should not be fumigated with hydrocyanic acid gas for at least six months after spraying.

A great deal of time has been devoted to the study of citrus fumigation in the United States, particularly in the State of California, and investigators in that country have expressed the opinion that fumigation should not be carried out when the temperature rises above 70 deg. Fahr. They also hold the opinion that there is some appreciable danger in fumigating trees carrying small fruit—i.e., at the period between the setting of the fruit and the time at which it reaches an inch in diameter. There is still a field for investigation on many aspects of citrus fumigation in the State of Queensland.

Fumigation, especially for the armoured scales such as red scale, is a very effective means of control. The gas generated penetrates to every part of the tree, and if it is of proper concentration employed under conditions that are both suitable and safe a very high percentage

of kill will be obtained. One decided hindrance, however, to the extensive employment of citrus fumigation in Queensland lies in the cost of equipment, which is undeniably heavy if it has to be incurred by each individual orchardist. Where the gas is generated by the pot system, operations have largely to be confined to night work, and a further disadvantage arises from the fact that the sulphuric acid must be handled with great care. On the other hand, if spraying is adopted, the spraying of a heavy foliage tree such as citrus is no easy task, because no matter how painstaking the operator may be it is difficult to reach every portion of the tree.

The remarks on fumigation have so far been confined entirely to the pot system of generating the hydrocyanic acid gas. Attention, however, must now be directed to the recent extensive use in Australia of calcium cyanide dust for citrus fumigation. The procedure in using calcium cyanide is briefly as follows:—Firstly, observations are made to determine whether or not the conditions are favourable for fumigation, then, if the conditions are satisfactory, the trees to be treated are covered with sheets, the trees are measured, and the appropriate doses of calcium cyanide dust are poured out and blown in under the sheets. After the expiry of the necessary fumigation period the sheets are then moved on to the next set of trees to be treated.

The Department of Agriculture and Stock carried out a number of preliminary trials with this dust on citrus trees in several districts, and in these preliminary trials, under the conditions then prevailing, good kills of red scale and white louse were obtained.

Where to Obtain Insecticides and Fungicides.

Many orchardists doubtless have their own agents or local dealers through whom they either do or can obtain their supplies of insecticides and fungicides, but, nevertheless, it frequently happens that the Department is asked where these may be obtained. For this reason it has been thought desirable to give the names of some of the dealers in or near the metropolitan area. The Australian Co-operative Fertilisers Limited, Roma street, Brisbane; Buzacott (Queensland) Limited, 371 Adelaide street, Brisbane; Southern Queensland Fruitgrowers' Association Limited, Cleveland; and Taylors and Elliotts Limited, Charlotte street, Brisbane, all handle various lines of insecticides and fungicides.

CHAPTER IV.

FUNGI AND BACTERIA.

A plant may be said to be diseased when, owing to some condition of its environment or due to the presence of some associated organism, it is not able to display its normal state of development. In its widest sense the term "disease" would include the results of insect depredation, but it more commonly serves to designate plant troubles of the undermentioned types. The study of diseased conditions of this nature comes within the realm of Plant Pathology and is the work of the Plant Pathologist.

1. *Non-Parasitic or Physiological Diseases.*—These include general or local disturbances of the normal physiology of the plant owing to unsuitable environmental conditions, such as poor drainage, soil deficiencies, &c. The nature of these diseases is often obscure and in many cases the actual cause is unknown. Examples will be found in blossom-end rot of tomatoes and citrus exanthema.

2. *Parasitic Diseases.*—In this class are included diseases due to attack by members of several groups of parasitic organisms of which by far the most important are the fungi and bacteria. The great majority of diseases manifesting themselves in the form of definite lesions, such as leaf spots, fruit rots, &c., are caused by the presence of species from one or the other of these two groups.

3. *Virus Diseases.*—These are due to the presence within the plant of an infectious principle of ultra-microscopic size. Although little can be ascertained regarding the nature of the causal agent in these diseases, the members as a whole exhibit relationships which suggest that the group is a natural one. There are two well-known representatives in Queensland—bunchy top of bananas and spotted wilt of tomatoes.

FUNGI.

To understand fully the nature of a fungus or bacterial disease it is necessary to have some realisation of what the causal organisms are like in their structure and habits.

The fungi are low down in the scale of the plant kingdom. Their nearest allies are the algæ, some of which constitute the simplest forms of plant life known, while the higher forms are represented by the seaweeds. In both algæ and fungi the vegetative state takes the form essentially of a slender tubular filament or by association of several filaments a tubular structure or flat plate may be formed. The external appearance may differ widely in the various species, which sometimes

superficially resemble the shape of higher plants. Growth, however, can normally take place from the ends of the filaments only and the solid structure of the higher plants with all their specialised organisation depending on cell division both parallel and at right angles to the direction of growth never occurs.

Some fungi closely resemble the algæ in both vegetative and reproductive characters and they have probably evolved from the latter group. One very important point of separation from the algæ, and higher green plants as well, is the fact that a fungus does not possess the green colouring known as chlorophyll. By the aid of this substance plants which possess it are able to build up out of the carbon dioxide of the air and water and salts from the soil all the material necessary for their growth. Since a fungus does not possess chlorophyll it is dependent for nourishment on material already elaborated by green plants, such as is to be found in dead and decaying organic matter or in the living substance of the plant itself.

Structure.

The vegetative part of a fungus is known as mycelium, and consists of slender cylindrical thread-like filaments. (Plate 3, fig. 1A.) These are very fine and delicate, their diameter being usually somewhere in the region of $\frac{1}{5000}$ of an inch. A single thread of mycelium is known as a *hypha*. The cavity of the filament may be continuous, as, e.g., in some of the moulds, but in all the higher fungi it is divided by partitions or *septa* into a number of cells. The mycelium is composed on the outside of a thin pliable membrane which is a product of secretion of the living substance within. It is formed of a material differing somewhat from the ordinary cellulose of plant cell walls and in many cases consists rather of *chitin*—the substance going to form the shell of insects. Within the cell wall and lining it is the actual living matter of the organism. This is known as *protoplasm* and consists of a clear jelly-like substance. There is usually in each cell a small area of very highly differentiated protoplasm enclosed in a delicate membrane of its own. This body, known as the *nucleus,* is the all-important organ of the cell and controls the various growth and life manifestations of the fungus, such as assimilation and reproduction.

In a young cell the whole of the interior is filled with protoplasm, but as the cell wall expands and elongates with growth spaces known as *vacuoles* are left which become filled with watery cell sap. Reserve food material is often present in the cell usually in the form of granules of glycogen or animal starch and bright refractive globules of oil. Some fungi have colouring matter permeating the cell wall or dissolved in the oil globules. Growth of a hypha is a simple process. The terminal cell elongates. The nucleus divides and a transverse septum is laid down separating off the daughter nucleus and thus forming two cells. The new

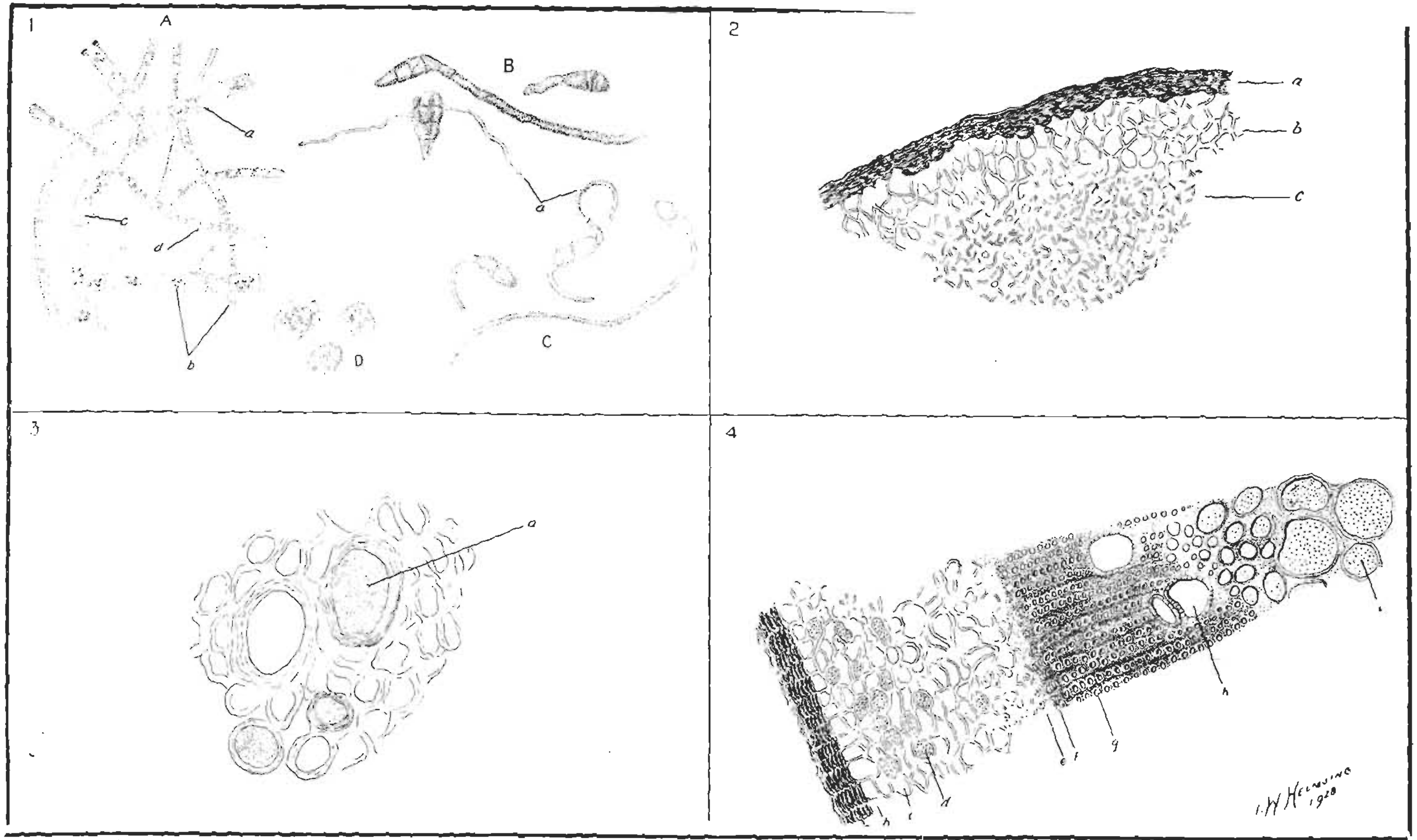


Plate 3.—Fig. 1A, portions of fungus mycelium; *a*, protoplasm; *b*, food granules; *c*, vacuoles; *d*, septum. B and C, germinating spores; *a*, germ tubes. D, Zoospore formation in *Plasmopara viticola*. Fig. 2, segment of transverse section through a sclerotium of *Sclerotium rolfsii*; *a*, hard outer cortex; *b*, pseudoparenchyma; *c*, medulla, x 210. Fig, 3, portion of transverse section of cabbage stem showing Black Rot bacteria (*Ps. campestris*) in vessel at *a*, x 210. Fig. 4, segment of transverse section of persimmon shoot; *a*, cork; *b*, phellogen; *c*, parenchyma cells of cortex; *d*, starch grains; *e*, phloem region; *f*, cambium; *g*, xylem cells of wood; *h*, larger xylem vessel; *i*, parenchyma cells of pith, x 210.

apical cell then enlarges and continues the growth as before. Branching takes place by means of a lateral extension from a cell of the hypha which takes on the function of a growing tip.

The form assumed by most of the less highly differentiated fungi in their vegetative state consists simply of a more or less interlaced mass of mycelial threads. Many of the higher forms by aggregation of hyphæ in a definite manner have produced more complex fungus bodies. The simplest of these is formed from the close interweaving, and in some cases fusion, of numbers of the hyphæ running together in a longitudinal direction. Definite fungal strands visible to the naked eye and known as *rhizomorphs* are thus produced. Sometimes the rhizomorph is differentiated into an outer thick-walled protective layer and an inner region of more delicate structure. A good example is seen in the black strands enveloping the roots of trees attacked by *Armillaria mellea.* (Plate 62.) The white strands given off from the base of mushrooms and commonly known as spawn are of a similar type. By means of these organs a fungus can travel with its delicate tissues undamaged for a considerable distance through the soil.

The mycelial aggregate may take a more compact form, giving rise to firm irregular or spherical bodies known as *sclerotia*. These, by virtue of the development of a thick resistant wall to the cells of the outer layers, can act as resting bodies and serve to enable the fungus to withstand such adverse conditions as exposure to drying. (Plate 3. fig. 2.) Reserve food material is frequently stored up within their cells. Examples of sclerotia are seen in the black irregular disc-like bodies scattered over the tubers of potatoes affected with Rhizoctonia Scab. The rounded form is fully described for the sclerotial fungus included under the heading of Mycelia Sterilia (Page 46).

More complex still are the structures developed by many fungi during their reproductive stage—e.g., such as are seen in the mushroom and bracket fungi. Here by interlacing and fusion of the hyphal filaments there may be formed a many-layered cellular structure resembling in superficial appearance that found in the higher plants. Such structure is known as *pseudoparenchyma*. It is shown in its simpler development in Plate 3, fig. 2.

Reproduction.

So much for the mycelium by means of which a fungus grows over or within its host and attains food and nourishment for its development. The vegetative stage in most fungi serves as a means to one end—that being the development of a reproductive stage by means of which the organism is perpetuated from generation to generation.

In a few, reproduction takes place simply by means of broken segments of mycelium; in the majority, however, there is developed a special reproductive organ consisting of a single cell or at most a small

cell aggregate known as the *spore* which corresponds in function to the seed of higher plants. Should a mature spore reach the right food material, and the temperature and moisture be suitable for development, its living contents will grow out into a slender delicate hyphal structure known as a *germ-tube,* which represents the first stage in mycelium development. With it commences once more the vegetative stage of a new fungus plant. (Plate 3, figs. 1 b, c.)

Spores are formed from the mycelium in two main ways—(1) *Endogenously*: In this case the contents of the modified mother cell known as a *sporangium,* become divided up into a number of smaller portions which may or may not develop cell walls of their own. These are finally liberated by rupture of the sporangium wall (Plate 5, fig. 1). In some cases, as e.g., in the fungus causing Irish Blight, the spores develop a fine filiform vibratile process known as *flagellum* which enables them to swim around in a film of surface moisture. Such spores are called *zoospores.* (2) *Exogenously:* Exogenous spores are produced from the ends of fertile hyphæ by a process analogous to budding. The top of the hypha becomes separated off by development of a septum, and the cell so formed gradually assumes the shape of the particular spore form of the species. Often the hypha is divided into a number of segments before shedding of the spores takes place, so that a chain of spores is produced. Spores produced in an exogenous manner are called *conidia* and the fertile hyphæ from which they are developed are known as *conidiophores.* (Plate 5, figs. 8, 9, 3b.)

Many fungi are *polymorphic*—i.e., they develop more than one spore form during their life cycle. (Plate 5, figs. 3, 5.) Commonly in one of these forms is represented a sexual stage. In the fungi this consists essentially in the union of the nuclei of two distinct cells either from the same or different fungal plants. The significance of this act is doubtful, though in some cases it may serve to invigorate the stock and preserve the characters of the race. The fruiting body developed in connection with the spores resulting from this act of union is usually referred to as the *perfect stage* of the fungus. Other methods of spore formation occurring in conjunction with a sexual stage are usually various modifications of the exogenous or endogenous types mentioned above. In the case of the occurrence of the former type the stage is usually referred to as the *conidial stage.*

The actual details of spore formation and the various supporting structures developed in connection with the process vary greatly in the different groups into which the fungi are divided, the groups themselves being largely established on consideration of the reproductive characters.

A description of some of the more characteristic types will be found in the chapter dealing with the classification of fungi.

BACTERIA.

The bacteria rank next in importance to the fungi as causal agents of plant diseases. At one time they were considered to be parasites only of animals—a view since shown to be quite erroneous by the discovery of members of this group acting as the causal agents in many serious plant troubles. The bacteria are usually attached to the true fungi or Eumycetes as a separate division known as the Schizomycetes or fission-fungi. They resemble fungi to a large extent in their general habits, though differing from them morphologically, being of simpler construction.

Bacteria appear as sphærical or rod-shaped cells of extremely minute size. A quite average specimen might have a diameter of less than $\frac{1}{25000}$ of an inch. (Plate 3, fig. 3a.) The cell is bounded by a thin elastic outer wall or capsule within which lies the living protoplasm. From the wall of the capsule may extend one or more vibratile filaments known as *flagella*, which confer the power of motion on the species possessing them. The flagella may be polar or diffusely scattered. As in the case of fungi, there is no chlorophyll developed. Numerous granules may be imbedded in the protoplasm, but a definite nucleus such as is found in the fungi and all the higher plants appears to be absent.

One of the chief differences between the fungi and bacteria is in their manner of growth and reproduction. In the former growth is continuous from the apex of a hypha and reproduction takes place by the use of a specialised spore. The bacterial cell has no apical growth. A slight extension takes place and then the individual divides into two by simple fission. The two cells may separate and become independent, or they may remain more or less loosely associated end to end when by frequent division of each cell a chain of individuals is formed. Successive division may take place after intervals of half to one hour. At this rate the progeny of a single cell may in twenty-four hours amount to many millions. Fortunately, lack of suitable food material or environment and the toxic action of their own secretion helps to keep the number down. A resting spore is formed by some bacteria. A portion of the protoplasm in a mother cell becomes somewhat denser, and round this is developed a special wall to form the spore. This appears as an ovoid refractive body lying within the mother cell. These spores are highly resistant to adverse conditions and can germinate readily after being subject to conditions fatal to the ordinary vegetative cell.

Most of the plant pathogens belong to the rod-shaped type. Of these the chief genera are *Bacterium*—non-flagellate; *Bacillus*—flagellate with flagella diffusely scattered; *Pseudomonas*—flagellate with polar flagella.

MYXOMYCETES.

This primitive group of slime fungi are often associated with the Eumycetes and Schizomycetes as a third division, the Myxomycetes, under the term Fungi, using this name in a broad sense. The three divisions resemble each other in the absence of chlorophyll and certain characters resulting from this. The slime moulds constitute the lowest form of plant life, living as they do on the border line between plants and animals. They are unprotected in their vegetative state by a cell wall, and consist of a naked mass of jelly-like protoplasm. Most forms are saprophytes. One is the cause of the well-known Club Root of cabbage. None of the slime moulds are responsible for serious disease in this State.

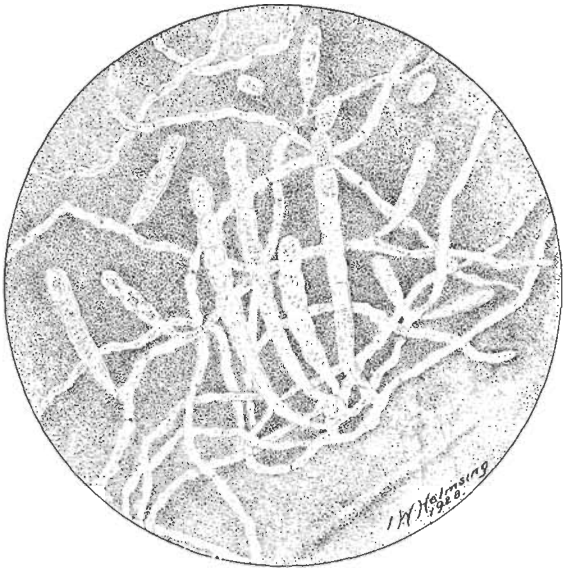
HABITS OF FUNGI AND BACTERIA WITH SPECIAL REFERENCE TO THE HOST PLANT.

To understand the effects a fungus may have on its host it is necessary to form some idea on the general structure of the flowering plants. It is therefore proposed to give here a brief outline of this subject.

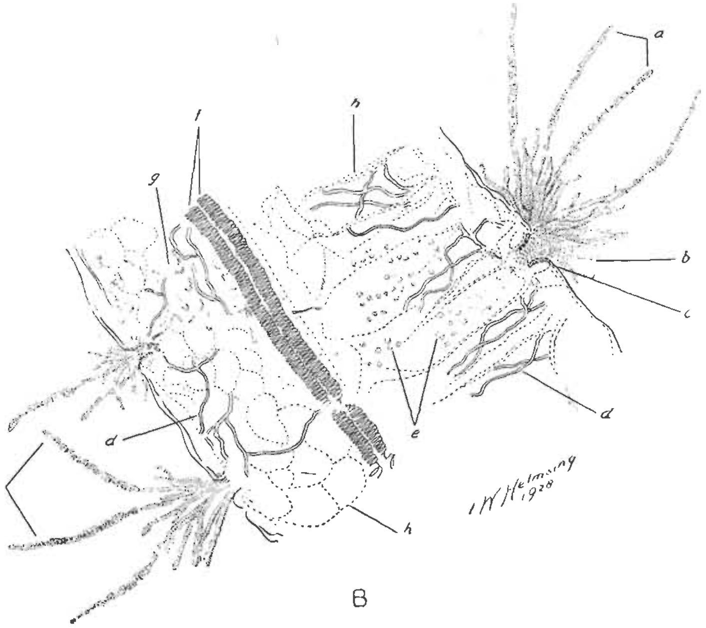
Structure of the Host Plant.

On general appearance a plant is at once seen to consist of roots, stem, and leaves, and with each of these is associated differences in structure and function. The roots serve to anchor the plant to its substratum and act as the absorbing organs for obtaining the water and mineral salts necessary for nourishment and for maintaining turgidity. If there is not sufficient water available to fill and distend the cells and thus confer a state of rigidity even on soft tissue, sagging and wilting will occur. The trunk and branches serve for support and display of the leaves and provide channels of communication between these organs and the roots. The leaves are the site of the elaboration of the various food constituents for which they serve as the receiving depôt. By means of the complex green colouring matter known as *chlorophyll* which is present in them, leaves are able to make use of the sun's light energy and by its aid absorb the carbon dioxide from the air and combine it with the water and mineral salts obtained from the soil by the roots. The first products of this chemical action are simple, but there is finally built up from these all the complex organic compounds which go to make up specialised plant structure.

The whole of the plant body, like that of the animal, is composed of a collection of minute cells. A plant cell differs from that of an animal in that it is provided with a wall of cellulose to which the rigidity of the plant structure is due. The individual cells are box-like or oblong and in general resemble the fungal cells described above. The cells of the leaf and other green parts contain embedded in the protoplasm, in addition to the nucleus and various food granules, small disk-like



A



B

PLATE 4.

Fig. A.—The ectoparasitic type of fungus. *Oidium erysiphoides* as it appears on the surface of a marrow leaf infected with Powdery Mildew, x 210.

Fig. B.—The endoparasitic type. Section of leaf of the nightshade (*Solanum nigrum*) attacked by the fungus *Cercospora solanacea* ; *a*, spores ; *b*, conidiophores ; *c*, stomata of the leaf ; *d*, mycelium of the fungus ; *e*, chloroplasts in cells not yet invaded ; *f*, conducting vessels of vascular bundle ; *g*, tissue disintegrating as result of fungus attack ; *h*, cell walls, x 210.

bodies known as *chloroplasts.* (Plate 4B.) These contain a fatty substance in which is dissolved green colouring matter—chlorophyll—on which as it has been shown the life processes of the plant depend. The higher plants differ from the fungi and algæ in that their cells have the power of dividing by walls parallel as well as at right angles to the direction of growth so that more solid structures can be produced. Young tissue consists of a mass of closely packed oblong cells, but as these distend somewhat with growth the walls separate slightly at the edges and minute intercellular spaces appear. It is by means of these spaces that the air reaches throughout the tissue, bringing with it the oxygen used in respiration. Should air be prevented access to any part such as by waterlogging of roots, &c., asphyxiation is likely to occur. In the plant there is nothing corresponding to the complex blood system of the animal which distributes throughout the whole body the oxygen on which life depends. Thus every cell of the plant must come in contact with air and breathe for itself.

The outer surface of a plant, at least in its young stages, is covered by a protective layer of cells known as the *epidermis.* This consists of a single layer of closely united cells whose outer wall is thickened by the deposition of corky or waxy substances which serve to prevent excessive loss of moisture and also protect the plant from invasion by parasitic organisms. At frequent intervals, especially on the under surface of leaves, minute funnel-like pores or *stomata* occur in the epidermis of the aerial parts through which air circulates to the inner tissue. (Plate 4B.) The stomata are rather a point of weakness in times of fungal or bacterial attack, as organisms unable to penetrate the protective epidermis are often able to gain entrance by their means. On the young fibrous roots very thin-walled tubular extensions of the epidermal cells act as the absorbing organs through which the desired soil solutions percolate. They are known as the *root hairs.* The delicate nature of these is sometimes made use of by soil-frequenting parasites which find in them an easy path to the inner tissues of the root. Developments from the epidermal cells of aerial parts may result in producing hairs, scales, &c.

In the branch and root of woody plants the epidermis later becomes replaced by a more substantial protective covering. A ring of cells lying just below the epidermis takes on the power of active division and is known as the *phellogen.* These cells divide by walls laid down parallel to the external surface and form a layer of closely-fitting oblong cells built up somewhat like bricks in a wall. The cells of this layer become impregnated with a corky material which with their tightly packed arrangement makes them specially suitable to resist adverse conditions of the environment and the attack of parasites. (Plate 3, figs. 4 a, b.) It is this layer, known as the cork, which makes many of the fungi

attacking woody tissues dependent on wounds for their entrance. The cork, together with some of the underlying tissue, is that part of a tree to which the common name of bark is applied. After cork formation the place of the stomata is taken by patches of loosely packed cork cells through which the air is able to penetrate. Apart from the bark phellogen it is not usually normal for mature cells to take on the function of active division. However, this does occur in the case of wounds or an invasion by parasites. A layer of contiguous cells surrounding the affected region assumes the function of a phellogen and deposits a protective layer of cork which cuts off the injured from the healthy tissue. The lesions of many fungi are definitely restricted in extent by a deposition of cork in front of their line of advance.

The radial growth of the stem and roots of the larger plants is due to the action of a ring of actively dividing cells having its origin in the growing point and extending back in the shape of a thin hollow cylinder situated some distance further in than the phellogen layer. This tissue in which active cell multiplication takes place is known as the *cambium.* From it are cut off on the side towards the centre of the stem cells which eventually become large cylindrical vessels, the walls of which become thickened and strengthened by a substance known as *lignin.* These cells in mass form what is commonly known as the wood and botanically as *xylem.* (Plate 3, fig. 4 e, f, g, h.) Besides lending support to soft tissue the xylem vessels serve as conducting tubes which convey water and dissolved salts from the roots to be used in the leaves. On the outer side of the cambium, cells divide to form a smaller number of narrow elongated cells known as *phloem* tubes, through which the food material elaborated in the leaves is conducted to other parts of the plant needing it. In some annuals and young plants the cambium may not be developed in a complete ring, in which case smaller patches of xylem vessels, cambium, and phloem, known as *vascular bundles,* form isolated woody strands running down the branch. Surrounding these and separating them from each other is a loose tissue composed of round or oblong thin-walled cells known as *parenchyma.* Parenchyma separates the phellogen and cork from the vascular tissue, and when present in the centre of the stem forms the pith. (Plate 3, fig. 4 c, i.) In the leaf, extensions of the vascular bundles of the branch form the veins. (Plate 4B, f.) Here the interlying parenchyma is particularly loose in arrangement so as to facilitate circulation of air amongst the chlorophyll containing cells and thus permit of ready assimilation.

Anyone wishing to go further into the subject of plant structure and physiology should provide themselves with "An Elementary Textbook of Forest Botany," by C. T. White, F.L.S.

Saprophytes and Parasites.

As mentioned elsewhere, one of the essential points of difference between the fungi and bacteria and the rest of the plant kingdom is the normal absence of chlorophyll. As this green pigment is a chemical necessary for the manufacture of the carbon compounds out of which is built the great bulk of the structure of plant life, it follows that the fungi and other forms lacking chlorophyll have to fall back on the higher green plants or organic products derived from these for their supply of carbonaceous material. A little thought will show that the animal kingdom is also ultimately dependent on green plants for its food supply.

With reference to their method of obtaining a supply of organic food, the fungi and bacteria can be divided into two main groups.

(1) *Saprophytes.*—Under this term are included all the multitude of organisms that live on dead plant remains. These they break down into carbon dioxide, ammonia, and simple mineral salts suitable for absorption again by the roots of green plants, assimilating at the same time substances suitable for their own nourishment. The saprophytes act as scavengers, and play a very important part in the economy of nature by preventing the excessive accumulation of waste material, which they place in a condition suitable for use again.

(2) *Parasites.*—As parasites are included all those organisms which are able to attack and obtain their nourishment at the expense of living plants and animals. This group includes all those fungi and bacteria causing definite plant disease.

The two groups are not clear cut. Sometimes an organism normally a saprophyte may invade and produce disease in a plant whose vitality is low on account of subjection to poor growing conditions or other detrimental agencies. These are known as *hemi-saprophytes,* as distinct from *true saprophytes,* which cannot attack a living host. Examples are seen in certain root rot producing organisms. Others, although capable of true parasitism, are able to live for a time on decomposing organic matter in the soil, and from there pass to a living plant should it come in contact with a suitable host. Organisms of this nature are known as *hemi-parasites.* Many species of *Fusarium* and *Rhizoctonia* causing crown and root trouble are of this type. The rusts and smuts are examples of the *true parasites* depending entirely on a living plant for their support.

Some weak parasites are only able to enter their host by means of wounds which rupture the normally resistant bark and expose the more delicate living tissue below. Some may even start as saprophytes on the dead tissue of the wound, and from there pass into the healthy region.

Examples of these types may be had from the fungi responsible for collar rot in citrus, and in many of the organisms attacking the woody parts of plants.

Some fungal parasites choose a member of the animal kingdom for their host. A few of these are parasitic on man and the higher animals. Others serve a useful purpose, since they attack and destroy many of the scale and other insect pests, over which in a wet season they may exercise considerable control. The fruiting stage of these *entomogenous* fungi can be seen as a white or reddish tuft protruding out from beneath the covering of the dead scale.

Ectoparasites and Endoparasites.

The parasitic fungi can be divided into two groups with respect to their method of living on their host. These are the *ectoparasites* and *endoparasites,* a grouping which is of considerable importance when control measures are being considered.

Ectoparasites are those fungi whose mycelial growth is out on the external surface of their host plant, where it forms patches of fine web-like covering. (Plate 4, fig. A.) From the hyphæ in contact with the epidermal cells short lateral peg-like branches are given off which penetrate the cells of the outer tissue layers, and from them absorb all necessary nourishment. The absorbing organs are known as *haustoria.* The Erysiphaceæ or powdery mildews are a large group of important plant parasites whose habits are of an ectoparasitic nature. This enables them to be effectively controlled by application of sulphur and sulphur compounds in the form of a dust or wet spray. Certain of the fumes given off by the sulphur cause the death of the superficial fungus mycelium without injuring the plant.

In *endoparasites* the spore on germination grows out into a delicate hyphal thread known as the germ-tube, which penetrates the epidermal layer by dissolving the outer cell wall, or, when not able to do this, by making its way through the stomata or breathing pore. The hypha then branches, and the mycelium spreads throughout the tissue of its host, either growing in an intercellular manner between the cell walls and sending short haustorial branches into the individual cells for food supply, or else itself penetrating both intercellular and cellular spaces in its ramifying passage through the host tissue. The final result is usually death of the tissue in the part invaded. (Plate 4, fig. B.) The dissolving of the epidermal wall by the germ-tube and the subsequent penetration of the mycelium through the cell walls of the inner tissue is accomplished by means of an enzyme secreted by the protoplasm of the growing tip, which has the power of dissolving cellulose. Some fungi and bacteria secrete a toxic substance which kills the host cells for some little distance in advance of actual hyphal growth. This in

a few instances may be of a distinct advantage to the plant, as the fungus is unable to obtain the living tissue required and dies. There are parasites, such as some of the smuts and rusts, which have reached a high degree of adaptation with their host, and no actual death of the tissue or *necrosis* as it is called takes place, although the mycelium may be present throughout the cells.

When once the fungus mycelium has penetrated within the tissue of its host it becomes more or less protected from the effects of external fungicidal applications. As the plant possesses nothing corresponding to the blood system of animals whereby a poison may be carried uniformly throughout the organism, it is necessary to fall back on a spray, which, when covering the surface of the susceptible host, will kill the germ tube before it can gain entrance to the interior. For endoparasites a spray such as Bordeaux or Burgundy mixture therefore becomes necessary.

Effect—the Parasite and the Plant.

The reaction between the host and parasite is usually specific for the fungus or bacterium attacking and the host species attacked. There are thus formed characteristic types of injury for each disease. Much often depends on the ability which the host displays in the development of a protective corky layer around the affected region, the lesion by this means being limited to areas of definite size.

Leaf infection usually results in spots of various size, shape, and colour. The plant may cut off the affected part by a corky layer, when the centre may drop out, leaving a shot-hole condition. The attack of woody parts may result in the formation of open wounds or cankers or extensive dry rot. When juicy fruit or succulent tissue is attacked a soft rot is commonly the result, especially when bacteria are the causative agents. The attack of a soil-frequenting organism may result in root or collar rot, or the water-conducting tissue may be invaded. In this case a wilting or gradual declining of the aerial portion of the plant is often the first symptom noted. When the leaves commence to die more or less uniformly from the margin, root trouble can usually be looked for—the region furthest from the source of water supply feeling the effect first. The fungus does not always kill the tissue of the host, but may stimulate its abnormal development. This occurs in the production of such malformations as peach-leaf curl, witches' brooms, fungus and bacterial galls, &c. Abnormalities also occur as a result of restriction in normal growth.

CHAPTER V.*

CLASSIFICATION OF FUNGI.

The fungi are separable into four main divisions—The Phycomycetes, Ascomycetes, Basidiomycetes, and Fungi Imperfecti.

1. PHYCOMYCETES.—This is the lowest class of the fungi and includes species which exhibit characters indicating a relationship with the still more primitive algæ. The mycelium is a continuous multinucleate tube rarely developing septa and is never compacted into a definite tissue. The Phycomycetes are divided into two subclasses.

(*a*) *Oomycetes.*—Here the sexual reproduction is by union of the contents of a small male cell or *antheridium* with that of a larger female cell or *oogonium*. The spore resulting from this type of union is known as an *oospore*. The asexual reproduction is typically by means of motile zoospores which develop within a rounded sporangium. Sometimes the sporangium by suppression of zoospore formation takes the form of a conidium. Within the Oomycetes are included the causal agents of several very important diseases such as *Phytophthora infestans* causing Irish blight and the various downy mildews. In these parasites the oospores, when present, are usually formed within the tissue of the plant and owing to the thick resistant wall which they develop serve as resting spores. The conidia are delicate thin-walled spores developed from the tips of much branched conidiophores which, projecting up from the surface of the host, give the characteristic downy appearance (Plates 3D, 46).

(*b*) *Zygomycetes.*—In this subclass sexual reproduction consists in the union of two practically similar cells and the resultant spore is known as a *zygospore*. The group includes many of the common moulds such as are found growing on stale bread, &c. These fungi are not as a rule of a strongly parasitic nature, but some may cause extensive storage rots to over-ripe fruit and vegetables when these are slightly injured or subject to moist or otherwise bad conditions of storage. One example is the rotting of sweet potatoes caused by *Rhizopus nigricans*. The asexual and usual method of reproduction in this mould is by means of a rounded sporangium, produced by the swelling of the ends of slender sporangiophores within which are developed many numerous small round spores. The spec-like sporangium can usually just be made out with the

* This chapter is of a somewhat technical nature, but it has been included for the benefit of those readers who may desire further information regarding the more important groups of fungi.

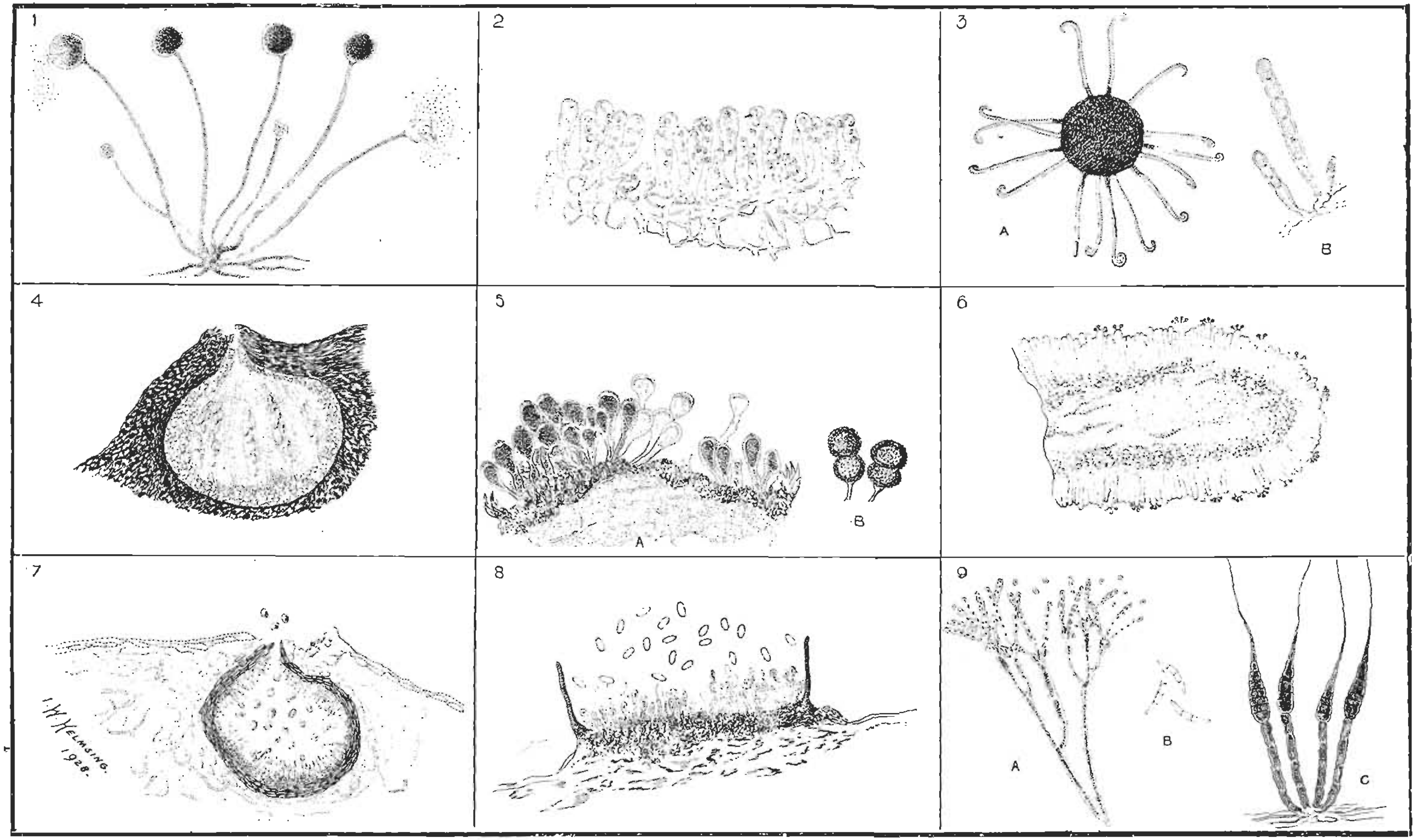


PLATE 5.—FRUITING BODIES OF SOME TYPICAL FUNGI.

1. *Rhizopus nigricans*. 2. Asci of *Taphrina deformans* on surface of curled peach leaf. 3. *Uncinula australiana*—A, perithecium; B, conidial stage. 4. Perithecium and asci of *Glomerella cingulata*. 5. *Puccinia prunispinosæ*—A, uredosorus on peach leaf; B, teleutospores. 6. Section through the gill of a mushroom. 7. Section through orange rind showing pycnidium of *Phoma citricarpa*. 8. Section through acervulus of *Glœosporium lindemuthianum* on French bean. 9. A. *Penicillium expansum*; B. *Fusarium* spores; C. *Alternaria solani*. (Figures x 210.)

naked eye. (Plate 5, fig. 1.) A few of the moulds are useful commercially. These have the power of secreting an enzyme or ferment made use of in the fermenting process of some distilleries. Power alcohol is being prepared from cassava and other starchy material by means of species of *Mucor.*

2. Ascomycetes.—The members of this large group are characterised by having the spores of the perfect stage developed endogenously in a special sac-like mother cell known as an *ascus.* On this account they are sometimes referred to as the sac fungi. The nucleus of the ascus is typically the result of the union of a male and female nucleus derived originally from two different cells. Ascospore formation can thus be taken as representing a sexual act and is therefore regarded as the perfect stage. In the Aspergillaceæ and Erysiphaceæ some forms show differentiation into a large female cell or oogonium and a smaller antheridium. The latter fuses with the former to produce the zygote from which the asci finally arise.

The number of spores produced in an ascus is usually definitely eight, but fewer or a multiple of eight sometimes occur. In the higher Ascomycetes the asci are developed on a special cushion of compact interlaced hyphæ known as a *hymenium.* On this they appear as an even layer of erect baton-like cells, separated from each other somewhat by the development of sterile cells known as *paraphyses.* The hymenium may be saucer-shaped and open to the exterior, or the margin may become incurved so as to form a closed receptacle lined by a layer of asci. The open type is known as an *apothecium,* the closed as a *perithecium.* Most members of the group are capable of producing conidia, and in some these constitute the main means of reproduction. The forms taken are many and varied. The mycelium is septate, and by definite aggregation of hyphæ specialised structures are formed by some species. These, however, do not attain the complexity of the next and highest group, the Basidiomycetes.

The Ascomycetes can be divided into three groups.

(*a*) *Plectomycetes.*—In this section a definite hymenial layer is absent. The asci may be developed unprotected on the surface of the host, as e.g. in the case of the family Exoascaceæ, one member of which, *Taphrina deformans,* causes peach-leaf curl. Here they are distributed over the affected region as minute oblong sacs projecting up from the surface of the leaf. (Plate 5, fig. 2.) In the Aspergillaceæ and Erysiphaceæ, adjacent hyphæ grow up around the group of asci developing from the oogonium and form a minute cottony ball of more or less closely interlaced threads completely enclosing them.

The family Erysiphaceæ, including the powdery mildews, is a very important and characteristic group. The mycelium of these fungi is entirely superficial, and forms a fine white web-like coat over the surface of the host plant. From this external mycelium short absorbing organs

or haustoria are given off which penetrate the surface cells of the host, and from them obtain all the necessary nourishment. Conidia are usually produced in abundance. They consist of straight, erect hyphæ, from which chains of thin-walled oval or rounded cells are cut off by the development of successive septa. (Plate 4, fig. A.) The name Oidium, which was given to this stage before any connection with an ascus fruit was discovered, is still in common use. The patches of Oidium fruit stand out on the surface of the host as of a more flowery nature than the web-like mycelium from which they arise. The ascus stage is developed later, and is often of rare occurrence or absent. The perithecia are often provided with appendages in the form of stout radiating hyphæ of definite shape. (Plate 5, fig. 3A.) These are largely used in defining the genera. It is to the appearance of clusters of these fruiting bodies that the Erysiphaceæ owe their name of powdery mildews. Since the perithecia are more resistant to environmental changes, they usually serve as the resting stage, whereby the fungus is carried from one season to the next. The superficial nature of the powdery mildews makes sulphuring particularly applicable to their control.

The yeasts belonging to the genus *Saccharomyces* are fungi which have lost the power of normal mycelial development. They consist of isolated rounded or oval cells which multiply very rapidly by a process of budding. Their use commercially is dependent on the power of the protoplasm to secrete enzymes which are able to ferment carbohydrates with the production of various substances, including alcohol.

(*b*) *Pyrenomycetes.*—These have a firm sphærical or flask-shaped perithecium, lined internally with a definite hymenium and bearing an opening at the apex for the liberation of the spores. (Plate 5, fig. 4.) The perithecia may be situated free on the surface, or be more or less immersed in the tissues of the host. Several may be associated on a definite bed of closely interwoven hyphæ, known as a *stroma*. Conidial fructification is very common and takes many forms. In many Pyrenomycetes conidia constitute the main means of reproduction, and in some forms this stage was for long the only one known when the species had to be included in the Fungi Imperfecti. A number of important parasitic genera are included in this group, such as *Claviceps, Mycosphærella, Nectria, Venturia*, &c.

(*c*) *Discomycetes.*—In this group are included fungi having the mature fruiting body of the open saucer shape, known as an apothecium. The members are mostly saprophytes living on decaying vegetable matter, and only a comparatively few are parasitic.

3. Basidiomycetes.—This, the third and highest class of fungi, are characterised by the development in a more or less modified form of a special spore form known as a basidiospore. Typically, there is developed from the ends of fertile hyphæ an oblong club-shaped cell known as a

basidium. This cell in some of the lower groups is septate. From the basidium there is developed laterally, or in the higher forms terminally, a definite number, typically four, short peg-like stalks or sterigma, on the ends of which a single small rounded spore is formed exogenously. (Plate 5, fig. 6.) The union of two nuclei in the basidium before the development of the basidiospore represents a rudimentary sexual phase. Conidial fructification is not common among the Basidiomycetes. The mycelium is septate, and in the higher forms may be interwoven into very complex fruiting bodies, such are are found in the mushrooms, bracket fungi, &c.

There are four important orders in this class, each with its own special characters.

(*a*) *Ustilaginales.*—*Here are included the various smut fungi.* These are all obligate parasites, occurring only on living host plants, the majority of which can be found in the natural order *Graminaceæ,* including the cereals and grasses. The mycelium consists of delicate hyaline filaments living an intracellular existence within the tissue of the host, where it often fails to make its presence evident until the time of spore formation. When the plant is approaching maturity the mycelium becomes aggregated in certain organs of the host, commonly the ovary. Numerous cross walls divide the mycelium into short cells, the walls of which swell somewhat and finally disappear as the contents become rounded off, and secrete around themselves a dark thick wall. The resulting spores developed directly from the vegetative mycelium are of a type known as chlamydospores. The spores are usually rounded in shape, with the surface sometimes studded with minute spines. They are usually produced within the tissue of the host, where they form sooty pustules known as *sori.* Later, they are liberated by rupture of the host tissue as isolated spores, in pairs, or in small clusters known as *spore balls.* The spore in germinating gives rise to a promycelium, on which are developed conidia—this probably representing a rudimentary type of basidiospore formation. The smuts are the cause of many important diseases, especially among cereals. Infection may take place in two main ways. Since sori are commonly developed in the fruiting organs of the plant, spores may contaminate the surface of sound seed, and when this is sown the spores will germinate and infect the growing plant. In the other case spores may fall on to an ovary and then germinate and produce a delicate mycelium which penetrates the interior of the developing seed where it lies dormant until the seed commences to grow. In the former case treatment with a fungicide, such as copper carbonate dust, may be successfully applied. In the latter case this is useless, and other less simple methods have to be employed, such as soaking in water at a temperature which will kill the fungus but not affect the germ of the seed.

(*b*) *Uredinales.*—This is a highly specialised group of fungi commonly known as rusts, in which polymorphism is developed to a high dgree. Five different types of spore may be developed during the one life cycle. These are: *spermatia,* minute functionless conidia produced in an enclosed chamber known as the *spermagonium; æcidiospores,* small round spores cut off in succession from peg-like conidiophores lining the base of a cup-like receptacle known as the *æcidium; uredospores,* rounded thick-walled spores produced singly from the ends of simple upright conidiophores, clusters of which bursting through the epidermis are known as sori; *teleutospores,* also produced in sori, one, two, or several celled, and possessing the thickest wall of all the spore forms; *basidiospores,* rather delicate spores produced from the short promycelium of the teleutospore which acts as a basidium, giving rise to sterigma and basidiospores. (Plate 5, fig. 5.)

In many rusts one or several of these stages may be absent. The uredospore is probably the form most commonly met with. Teleutospores are often developed towards the end of a season, when their resistant structure suits them to act as a resting spore.

Some rusts exhibit the phenomenon of *heterœcism.* The *heterœcious* rust has some stages in its life cycle developed on one host, while the remainder are found on a different plant. In England, the common wheat rust forms its spermagonia and æcidia on the Barberry. The æcidiospores infect the wheat on which host are produced the uredo- and teleutospores. The latter after a period of rest produces the basidiospores, which reinfect the Barberry. In Australia, this wheat rust is *autœcious,* as the stages on the Barberry are absent, and the life cycle is restricted to the wheat.

It is also found that some rust varieties show extreme specialisation regarding the host which they will attack. It is sometimes possible to separate several strains of a particular species of rust which, although apparently identical morphologically, are nevertheless restricted in their powers of infection to different varieties of plants. Such forms are referred to as *biologic species.*

(*c*) *Hymenomycetes.*—This order includes the mushroom type of fungi. They are mainly saprophytic, living on decaying vegetable mould and other dead plant tissue. A few, such as *Armillaria mellea* and several of the bracket fungi, are important parasites. In this group the basidiospore development is typical—four spores being developed from each nonseptate basidium. Various structures are developed for support of the basidia, which are produced in definite hymenial layers, consisting of short upright club-shaped cells separated by sterile cells of similar shape known as paraphyses. The many and varied forms seen in the fruiting bodies of fleshy fungi all represent specialisation for

increasing the area of the hymenium and aiding spore distribution. The hymenium is thus seen covering the gills of the mushroom and lining the pores of the bracket fungi, &c. (Plate 5, fig. 6.) The development of rhizomorphs and cellular structure simulating the tissue of higher plants is common among the Hymenomycetes.

(*d*) *Gasteromycetes.*—This final order includes the puff balls. Their growth is similar in general character to that of the Hymenomycetes, except that the hymenium is completely enclosed in a closely-woven mycelial sac until the spores mature, when they are liberated by rupture of the outer coat.

4. Fungi Imperfecti.—Besides the above three classes there is a very important group known as the *Deuteromycetes* or *Fungi Imperfecti.* They include fungi in which a perfect stage of reproduction has not been discovered. A conidial stage is present, but in the absence of knowledge regarding a sexually produced spore the fungus cannot be placed satisfactorily in any of the above groups. The forms taken by the conidial fructification in the different genera are many and varied. A number of these are similar to conidial stages belonging to genera of the Ascomycetes and some Basidiomycetes. From time to time the perfect stage of an individual is discovered and then the species has to be removed from the Fungi Imperfecti to the position indicated in the other classes. No doubt many will find their natural resting place in this manner, but others will always remain which have lost entirely all trace of their perfect stage. The forms taken by the spores in the different species vary greatly. They may be hyaline, dusky, or coloured; circular, oval, eliptical, or elongated; one, two, three to many septate. Some are muriformly septate—i.e., divided by both longitudinal and transverse walls. Others are provided with bristle-like appendages.

There are four orders based on the type of conidial fructification.

(*a*) *Sphæropsidales.*—In the members of this order the conidiophores are simple peg-like structures thickly lining a rounded, elliptical, or flask-shaped receptacle known as a *pycnidium.* The wall of the pycnidium is formed of closely interlaced hyphæ and is of varying colour, shape, and thickness giving characteristics on which are based the various families into which the group is divided. The pycnidia with reference to their host may be superficial or more or less immersed in the plant tissue. The apex may terminate in a pore through which the spores are extruded. In other cases there is no special opening, and the spores are liberated by rupture of the wall. (Plate 5, fig. 7.) Members of this group are responsible for many leaf spots and stem diseases. There are included the important genera, *Phoma, Phyllosticta, Diplodia, Phomopsis, Sphæropsis, Septoria,* &c.

(*b*) *Melanconiales.*—In this order the pycnidium is absent. The conidiophores, which are simple, arise from a cushion of closely woven hyphæ known as a stroma. The stroma is usually sunken just below the epidermal layer, which becomes ruptured by the developing spores. This type of fructification is known as an *acervulus*. (Plate 5, fig. 8.) Within the group are included the genera *Glœosporium* and *Colletotrichum*, which are responsible for many of the diseases known as Anthracnose.

(*c*) *Moniliales.*—Both pycnidium and acervulus are absent. The conidiophores arise singly or in small groups on the surface of the host from more or less aggregated mycelial strands below. The stomata or minute breathing pores of the plant are frequently availed of as a means of egress. The genera of this order show much diversity in the form taken by the conidiophores. They may be scattered or aggregated into definite bundles. They may be simple or variously branched. The conidia are in some developed singly from the tips. In others long chains of developing spores are formed. (Plates 5, fig. 9, and 4, fig. B.) The group includes some very serious parasites. Some of the more important genera are *Penicillium, Botrytis, Thielaviopsis, Cladosporium, Macrosporium, Alternaria, Cercospora, Fusarium*, &c.

(*d*) *Mycelia Sterilia.*—In addition to the forms above described there are a number of fungi grouped together for convenience under the name of *Mycelia Sterilia,* since no spore formation has ever been observed in connection with them. Their sole method of reproduction is a vegetative one by means of mycelial fragments or by sclerotia, which latter are of common occurrence throughout the group.

One member of the Mycelia Sterilia, probably that known to science as *Sclerotium rolfsii,* causes considerable trouble amongst garden and other plants in Queensland, when the damage usually takes the form of a crown rot. The fungus appears as white mycelial threads extending over and radiating out from the affected region. (Plate 63.) The threads may become interwoven to form a dense cottony weft which usually becomes studded with numbers of shiny brown sclerotia of about $\frac{1}{16}$ inch diameter. In the formation of the sclerotia the mycelium at different points becomes massed into a minute cottony ball. This is at first composed of more or less interlaced hyphæ, but by subsequent branching and interweaving a firm structure is formed. The cells of the outer layers become somewhat thickened and form a brown resistant covering. In their final appearance these sclerotia are not unlike radish seeds.

CHAPTER VI.

FUNGICIDES AND DISEASE CONTROL.

Three main lines of attack are available to the agriculturist for the control of plant disease. These are: The use of resistant varieties; the employment of special cultural methods; and the application of fungicides.

RESISTANT VARIETIES.

It has been found that in various crops there may arise from time to time a certain variety or individual which exhibits a marked resistance to a particular disease to which others of the same species are specially subject. This resistance is sometimes the result of an alteration in the anatomical structure of the variety in question which makes it more difficult for infection to take place. For example there may be a thicker outer wall developed by the epidermal cells of the resistant plant. More often, however, resistance is due to physiological factors whose exact nature is usually difficult to ascertain. Some differences in the composition of the cell sap, although so slight as to be undeterminable, may be sufficient to inhibit the growth of the parasite. Resistant varieties can often be improved by breeding and selection, and when suitable commercially their use constitutes the ideal method for overcoming loss from disease. As the resistance is an inherent character of the plant itself, other troublesome control measures can be dispensed with. The growing of wilt-resistant varieties of tomatoes is a case in which a serious fungus disease has to a large extent been overcome by this method. Some varieties avoid disease owing to the fact that they are early or late maturing, and their susceptible period of growth is passed through during that part of the season in which the parasite is inactive. Some useful wheat varieties owe their freedom from rust to this habit.

It should be remembered that, owing to variations in local growing conditions and also probably to the presence of more than one strain of the parasite, a variety may show resistance only in one particular region. Each district has therefore to try out varieties for itself. Also the resistant qualities have to be maintained by careful selection, or otherwise they may be gradually lost. Not only disease resistance, but general vigour and productiveness, can be greatly increased or diminished according to the amount of attention or lack of attention devoted to selection for propagation purposes.

CULTURAL METHODS.

Control measures involving special cultural practice have two main objects in view—(1) To increase the crop's endurance by supplying it

with its optimum conditions for growth; (2) to reduce to a minimum the amount of infectious material present by means of general sanitation and crop rotation.

Improvement of Growing Conditions.

It is a fact observed by most growers that it is usually the plant showing poor growth which is damaged most by disease. The strong vigorous individual, although attacked, is not the same commercial failure, as it is in a better condition to outgrow the effects of the parasite. Moreover, there are some weak parasites which can attack their host only when this is in an unhealthy condition. In attempting to produce a vigorous plant, a rank succulent growth, such as sometimes follows excessive use of nitrogenous manure, should be avoided, since the soft tissues of these plants are often responsible for a more extensive invasion by actively spreading parasites such as the fungus responsible for Irish blight.

The first objective in the control of disease should therefore be an attempt to obtain for the crop its optimum conditions of growth. For this purpose, careful consideration must be given to the drainage and judicious manuring of the land, if this is not altogether suitable for the purpose for which it is required. Good cultivation and if possible irrigation should be practised in order to maintain continuous growth.

The result of inattention to the maintenance of soil fertility can be seen at the present time in the unhealthy condition of many of Queensland's older citrus and other orchards which have been continuously cropped for many years without any attempt at replenishing the soil.

Bad drainage is probably one of the most common sources of trouble, and moreover this condition is not always apparent from a superficial examination of the land, as hardpan or an impervious bar may occur in isolated areas on otherwise well-drained land. Even if not completely killed by asphyxiation, roots subjected to waterlogging may be weakened to such an extent that they become invaded by various fungal and bacterial organisms of the soil which set up a root rot. On the aerial parts various forms of dieback may result from invasion of organisms only able to attack the plant in its weakened condition. Though the primary cause of injury may have been due to excessive accumulation of water, the effect on the plant often does not become evident until some time after this occurred, when the drying out of the soil leaves the plant to feel the effects of a diminished root system.

As several of the fungi attacking the root, crown, and branches of fruit-trees require a wound to enable them to penetrate through the highly resistant bark, care should be taken that injuries are not given during cultivation and pruning. If large branches have to be removed the cut should be made clean and the surface covered with Bordeaux paste.

Sanitation.

In some cases the grower himself is largely responsible for breeding up a disease on his own farm. Much can be done to keep disease in check by merely following out simple precautions for general cleanliness. As refuse from a diseased crop may be bearing the fruiting bodies and spores of the organisms causing disease, all infected material should be carefully burnt as soon as the crop has ceased to be productive. If the disease is observed to be starting in a small area, its spread may sometimes be checked by immediate destruction of the affected plants. Care should be taken that disease is not carried from infected to healthy areas by means of contaminated clothes, boots, pruning tools, &c.

Rotation of crops will allow parasitic organisms to die out of infected fields, and should be practised whenever possible. Rotation is especially necessary in the case of such fungi as species of *Fusarium* and *Rhizoctonia,* which are often able to maintain a saprophytic existence on dead organic matter in the soil and will from this pass to a suitable living host should one become available. Such fungi can often retain their soil existence for considerable periods, and if possible allowance should be made for at least a three-year interval between plantings of a crop susceptible to a disease with which the field has become infected.

A seed-bed should always be located on land near which the particular crop or a closely related one has not been grown previously, and if virgin soil can be used so much the better. If a suitable site is not available and the crop is one subject to soil-borne diseases, sterilisation of the bed may be resorted to.

Disease may be introduced into a clean area on infected seed or by using cuttings, &c., from diseased plants. Examples of this are seen in the introduction of potato scab by the use of infected sets, and in the spread of Panama disease of bananas by planting suckers from diseased stools. If possible, seed, cuttings, tubers, &c., should be obtained from a district in which disease is not known to be present. If contamination is suspected, various methods of sterilisation may be practised. This is advisable as a routine procedure with those crops subject to seed-borne disease.

DIRECT CONTROL BY THE APPLICATION OF FUNGICIDES.

As was pointed out in Chapter 4, the development by fungi of an ectoparasitic and endoparasitic habit of growth opens up two methods for their destruction. Ectoparasitic fungi, living as they do on the surface of their host, can be killed by direct contact with a suitable fungicide. For this purpose, sulphur applied in the form of a dust or as sulphur compounds in solution has proved most useful. Under warm conditions the sulphur reacts with the oxygen and water vapour of the air to produce a volatile compound to the action of whose fumes the mycelium of the

fungus quickly succumbs. The class of diseases known as the powdery mildews are treated by this method. The endoparasitic parasites once within the tissues of their host are safely sheltered from the effect of fungicidal applications. To control such invaders it is necessary to get in early and prevent infection from taking place. For this purpose all the susceptible parts of the plant must be covered with a thin film of poison which, while it is not injurious to the plant itself, will affect the fungus to an extent that will prevent the germ-tube put forth by the developing spore from penetrating the surface. Owing to their protective outer covering, it is not usually possible to kill the spores themselves before germination without using a spray too strong for the plant to stand. Various copper compounds have been found to give the best results in resisting the attack of endophytic fungi. The most commonly used of these fungicides are Bordeaux and Burgundy mixtures. When properly prepared these will not injure the plant, nor are they sufficiently poisonous to be harmful should sprayed fruit be consumed with the chemical still present.

The copper fungicides are usually applied in the form of a wet spray. Of recent years there has been a tendency in some countries to apply the poison in the form of a dry powder as a dust. Reports of the results obtained from dusting as compared with the wet spray are rather conflicting, but dusting on the whole would appear to be a less effective method, especially during a season of heavy rainfall.

The advantages of the dust over the wet spray are—

(1) The ease and rapidity with which a dust may be prepared and applied reduces labour costs.

(2) The apparatus used is less costly and lighter to work with.

(3) No water is needed, which is a consideration in some localities.

The chief disadvantages are—

(1) The results obtained from dusting are often not equal to those obtained from the application of a wet spray.

(2) In order to obtain proper covering it is necessary to dust when the air is comparatively still. If the surface of the plant to be treated is at all shiny, moisture must be present to ensure adherence.

(3) The adherence of a dust is not usually as great as that of a spray, which necessitates more frequent applications.

Reliable copper dusts applied under suitable conditions should give a control sufficient, when the other advantages are taken into consideration, to justify their use. Unfortunately these necessary conditions are not to be had to order, and in the present state of knowledge regarding dusting this procedure cannot be recommended as a universal substitute for the wet spray. It should be noted that the above remarks do not

apply to dusting with sulphur, which has been proved to be very effective for the purposes for which it is employed. The difference is that sulphur acts by reason of the fumes which it gives off, and complete covering and long adherence are not of such paramount importance.

To obtain best results from a minimum expenditure of the material, the spraying machines should be capable of delivering the fluid at high pressure through a suitable nozzle so that a fine mist-like spray is produced. This will give a more even and thorough coating than the coarser spray of the low-pressure pump. Spraying on showery or wet days should be avoided as far as possible, as several hours is necessary for a spray to dry thoroughly and retain its lasting properties.

Care should be taken that the crop is well covered with spray during moist or muggy weather, as atmospheric conditions of this nature are very suitable for spore germination and are thus conducive to the spread of most fungus diseases. Hot dry days usually serve as a check to disease, and the delicate spores of many fungi become quickly desiccated during such times.

The number of different specifics which have from time to time been advocated for the control of various diseases is considerable. There are, however, a few which have a more or less general application and which have stood the test of long usage. The more important of these will be shortly described below.

Bordeaux Mixture.

This spray is probably the most widely used fungicide at the present day. It consists of a somewhat indefinite mixture of copper compounds, including basic sulphates, in which the copper has been precipitated until practically none remains in solution. The spray is therefore non-injurious to the plant, since the injurious copper salts cannot be absorbed into the tissue of the living organism unless in the soluble form. Minute quantities are, however, dissolved by the acids of the plant juices, and these are sufficient to prevent fungus infection. The poison in these minute doses also acts as a stimulant to the plant itself, and thereby promoting a more vigorous growth aids it in resisting the invasion of the attacking parasites.

Formula.

Bluestone (copper sulphate)	6 lb.
Burnt or quick lime	4 lb.
Water	40 galls.

This is briefly referred to as a 6-4-40 formula.

Dissolve the blue unt of water in a
wooden or copper vess best done by tying
them in a piece of sack he top of the water

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overnight. Powdered bluestone can now be obtained, which dissolves very readily. Only wooden or copper vessels can be used to contain the bluestone solution, as this chemical will quickly eat through iron. Wooden casks form convenient receptacles.

Slake the lime in another vessel by the gradual addition of small quantities of water, when the heat generated will aid the reaction. After slaking is complete, water is added to make up the remaining half of the total required. Only best freshly burnt lime should be used, as otherwise there is likely to be an excessive amount of useless residue, and the final composition of the spray will be affected. If burnt lime is not available, good-quality hydrated (not air-slaked) lime can be used, but half as much again is required. It is usually difficult to prevent burnt lime from becoming air-slaked in moist climates, but this difficulty may be overcome by slaking the lime before it deteriorates, and keeping under water. For convenience in using later, store a known amount in a known volume of water.

The two solutions, bluestone and lime, are poured simultaneously through a fine strainer into a third container, or the spraying vessel and the mixture stirred well for a few minutes. This method gives a fine gelatinous precipitate which does not readily settle out. If necessary, one solution can be poured directly into the other, provided the latter is kept well stirred during the process. Concentrated solutions should not be mixed before dilution, as the resultant precipitate tends to be of a granular formation and its spreading and adhesive properties are poor. For the same reason the two solutions should be quite cold before mixing. Bordeaux mixture should be used as soon as possible after preparation, as it loses its gelatinous nature after several hours' standing and settles out in the granular form.

It sometimes happens that the lime used is of poor quality and the resultant mixture may then contain an excess of bluestone. This must be avoided, as the soluble copper salt is able to cause injury to the plant sprayed. An excess may be tested for by applying blue litmus paper (obtainable from a chemist) to the layer of clear liquid on the top of the spray. If the colour of the paper turns to red, more lime must be added until there is no change. A rough test is given by allowing a clean knife-blade or bright iron nail to remain in the mixture for a few minutes. If on removal this shows a brown coating of copper, more lime is required.

If a crop is to receive frequent and regular applications throughout the season, as is required for many of the foliage diseases, the above formula can be reduced to one consisting of 4 lb. of bluestone and 4 lb. burnt lime to 40 gallons of water. It is necessary to still further reduce the bluestone content for a summer spray for certain deciduous fruit-trees.

It is sometimes found convenient to make up a stock solution of bluestone and lime: 50 lb. of bluestone is dissolved in 50 gallons of water in a wooden vessel; 50 lb. of quicklime is slaked and water added to make up to 50 gallons. The solutions will keep well if protected from evaporation. One gallon of each will contain 1 lb. of bluestone or lime respectively, on which basis the necessary dilution before mixing for the preparation of any quantity can easily be calculated.

Certain proprietary mixtures, usually in the form of a paste or powder, are now on the market, for which it is claimed that they will form Bordeaux mixture on addition of the required amount of water, thus doing away with the trouble of preparing the home-made article. There are, however, some disadvantages in the use of these mixtures—

(1) They are usually more expensive than the home-made spray.
(2) The exact composition varies with the different makes, and it is therefore sometimes difficult to prepare a mixture of definite strength.
(3) It is found that some of the ready-mixed powders do not give such a fine suspension as the home-made mixtures, so that their spreading and adhesive properties are poorer.

However, if a reliable brand is obtained, these mixtures serve a useful purpose for the treatment of a crop for which it is not desired to acquire the apparatus necessary for home mixing.

Lead arsenate and nicotine sulphate may be added to Bordeaux mixture to give a spray combining both fungicidal and insecticidal properties.

Bordeaux and Oil Emulsion.

This spray has been recommended largely for spraying citrus trees. The addition of the oil has two advantages. In the first place it acts as a spreader giving a better covering. Also it exerts a controlling influence on scale development, and thus counteracts to a certain extent the disadvantages sometimes arising from the killing of entomogenous or insect-destroying fungi by the Bordeaux itself.

Take of a good brand of red oil an amount equal to 1 per cent. of the total volume of spray to be used. Emulsify this thoroughly in one to two times its own volume of water, and then stir well into the mixed Bordeaux. Care must be exercised that the oil is well emulsified before adding to the Bordeaux.

Concentrated kerosene emulsion may be used in place of red oil, the amount used being calculated on the total kerosene present.

Bordeaux and Resin Sticker.

For use in districts subject to heavy tropical rains the adhesive properties of Bordeaux mixture may be increased by the addition of a resin mixture.

Dissolve 1 lb. of washing soda in 1 gallon of boiling water. Then add 2 lb. of resin, which may be crushed into small particles, and boil until the mixture is clear. One gallon of this when cool can be added to every 25 gallons of Bordeaux spray.

Bordeaux Paste.

This is often useful for painting wounds, pruning cuts, &c., to prevent the invasion of rot-producing organisms.

Slake 2 lb. of quicklime in ½ gallon of water. Dissolve 1 lb. of bluestone in another ½ gallon. Mix equal quantities of the two solutions to give the amount of paste required.

Burgundy Mixture.

This spray is more favoured than Bordeaux by some growers, as it is somewhat easier to prepare and can be used when good quicklime is not available. There is little to choose between the fungicidal values of the two mixtures when properly prepared.

Formula.

Bluestone	6 lb.
Washing soda	8 lb.
Water	40 galls.

This can be reduced, when spraying is to be frequent, to a 4-5¼-40 formula. The preparation is essentially the same as in the case of Bordeaux, using the washing soda instead of lime.

The washing soda may contain impurities, and it is therefore necessary to test for excess bluestone as in the case of Bordeaux. As an excess of soda, unlike lime, is known to cause injury in some instances, it is advisable to test the mixture with both red and blue litmus papers. If the blue paper is turned red, an excess of bluestone is present and more soda is required. If the red paper quickly turns a definite blue, too much soda has been used and more bluestone solution should be stirred in slowly until there is no colour change in the litmus.

Ammoniacal Copper Carbonate.

Bordeaux and Burgundy mixtures both have the disadvantage in that they leave a bluish-white covering over the surface sprayed. Ammoniacal copper carbonate, while somewhat inferior to these as a fungicide, can be used on fruit approaching maturity, since it is a clear solution leaving no stain.

Formula.

Copper carbonate	5 oz.
Strong ammonia	3 pints
Water	40 galls.

Make the 5 oz. of carbonate of copper into a paste by the addition of a pint or two of water.

Add the 3 pints of concentrated ammonia to about 2 gallons of water in order to make the solution easier to handle.

Stir the copper carbonate paste into the ammonia water until dissolved or until no more will go into solution.

Add water to make up to 40 gallons.

Lime Sulphur.

Lime sulphur, next to Bordeaux and Burgundy, is probably the most valuable fungicide at present in use. It is even more efficient than sulphur itself in the destruction of ectoparasitic fungi, the mycelium of which is destroyed by the fumes given off by certain of the sulphur compounds contained in the spray. Used as a protective spray against the invasion of endoparasites, lime sulphur is less efficient than the copper preparations. Weighing against this disadvantage is the fact that lime sulphur has considerable insecticidal value in the destruction of scales and mites. It therefore can be used with advantage when spraying with Bordeaux would cause the destruction of the scale insect destroying fungi, leading to an increase of the insect pests. Lime sulphur can often be used as a summer spray for certain deciduous trees which would be injured by Bordeaux.

Lime sulphur can be bought in the concentrated form ready prepared, or can be made in the orchard. The latter procedure is the more economical for large holdings.

Formula for home-made lime sulphur:—

Flowers of sulphur	100 lb.
Good burnt lime	50 lb.
Water	50 galls.

About half the water is placed in an iron vessel and brought to the boil. The lime is stirred in while this is heating. The sulphur is then mixed into a paste and added, and the vessel stirred until the lime is slaked and the contents well mixed. The rest of the water is poured in and the mixture boiled for three-quarters of an hour to an hour but not longer. The orange-red liquid is strained from any sediment and stored in an airtight container.

The composition of the home-made lime sulphur and also some of the commercial brands varies considerably. Any grower using the spray in quantity should therefore test the strength of the concentrated solution before diluting for spraying. This is done by using a Baumé hydrometer, from which the density of the solution is read off in degrees Baumé. The strengths to be used for various applications are usually specified for lime sulphur of a 33 deg. Baumé as standard. The accompanying chart, adapted from that supplied by J. A. Campbell in the New Zealand "Journal of Agriculture," will enable sprays of correct

dilution to be prepared from lime sulphur concentrate of various densities. First determine by means of a Baumé hydrometer the density of the lime sulphur to be used. Find the corresponding degree of density in the left-hand column. The figure in the same horizontal line in the column headed by the dilution required will give the amount of water to add to one part of the stock concentrated solution in order to give this dilution.

Density of Stock Solution in Degrees Baumé.	Dilutions Required, based on a 33° Baumé Standard.							
	1 to 10.	1 to 15.	1 to 20.	1 to 30.	1 to 40.	1 to 80.	1 to 100.	1 to 120.
25°	7·6	11·4	15.2	22·7	30·3	60·6	75·8	90·9
26°	7·9	11·8	15·8	23·6	31·5	63·0	78·8	94·5
27°	8·2	12·3	16·4	24·5	32·7	65·5	81·8	98·2
28°	8·5	12·7	17·0	25·5	33·9	67·9	84·8	101·8
29°	8·8	13·2	17·6	26·4	35·2	70·3	87·9	105·5
30°	9·1	13·6	18·2	27·3	36·4	72·7	90·9	109·1
31°	9·4	14·1	18·8	28·2	37·6	75·2	93·9	112·7
32°	9·7	14·5	19·4	29·1	38·8	77·6	97·0	116·4
33°	10·0	15·0	20·0	30·0	40·0	80·0	100·0	120·0
34°	10·3	15·4	20·6	30·9	41·2	82·4	103·0	123·6
35°	10·6	15·9	21·2	31·8	42·4	84·8	106·1	127·3

Lime sulphur as a winter spray for deciduous trees, or as a winter dressing for the trunk and branches of citrus, can be used at a dilution of 1 to 10 or 1 to 15. At 1 to 40 it can be used as a general summer spray for citrus. As a summer spray for deciduous fruits, dilution of from 1 to 80 to 1 to 120 becomes necessary.

It may be advisable to increase the spreading qualities of lime sulphur by the addition of a casein spreader.

Sulphur.

Sulphur applied as a dust is used extensively for the control of the powdery mildews caused by species of the Erysiphaceæ.

Sulphur dust may usually be obtained in two forms—

(1) Ground sulphur consisting of lump sulphur ground to a powder of varying degrees of fineness.

(2) Sublimed or flowers of sulphur formed by the condensation of sulphur vapour obtained by burning ordinary sulphur.

Sublimed vapour is often finer than many of the commercial brands of ground sulphur, but it possesses the disadvantage of containing small quantities of free sulphuric acid which may cause some foliage-burning and also make the application disagreeable to the operator. Ground sulphur is quite equal to flowers of sulphur when in the same state of division. It loses its bright yellow colour with increased fineness, and good ground sulphur should always be a lighter yellow than the sublimed form.

Fineness of the particles is of the greatest importance, as it confers on the sample greater covering power with more even distribution and better adherence. Fine division is also conducive to greater evolution of the fumes to which sulphur owes its fungicidal properties.

Lime to the extent of 25 to 50 per cent. is sometimes added to the sulphur. This enables a more thorough application to be made than would otherwise be economically possible. It also reduces the chance of burning should the sulphur contain an excessive quantity of free acid.

A still warm day should be chosen for sulphuring, and if the dust is applied while the dew is still on the leaves better adherence will be obtained.

Disinfectants.

The use of disinfectants may be necessary for the sterilisation of seeds of plants subject to seed-borne disease, or the vegetative parts such as tubers, suckers, &c., used for propagation purposes. Seed-beds are also treated with advantage if the ground is suspected of harbouring disease.

Seed disinfection is especially desirable when planting crops liable to seed-borne disease on new land or land that has received rotation. The danger of introducing disease to a clean area by means of contaminated seeds is thereby lessened.

The chemicals commonly employed for the purpose are corrosive sublimate (mercuric chloride) and formalin (40 per cent. solution of formaldehyde).

Owing to the great variation exhibited by these disinfectants in their action on different seeds and fungus spores, no general method can be given for their use. Corrosive sublimate is commonly used at a strength of 1 part in 1,000, i.e., 1 oz. to 6¼ gallons of water. Small quantities of solution are more easily prepared by the use of tablets obtainable from a chemist. The solution will corrode metal containers, which have therefore to be avoided. The time of immersion varies with the variety of seed employed from about five minutes to half an hour. When treating tubers, cuttings, &c., longer periods can be used. Great care must always be taken when working with corrosive sublimate, as this chemical is a deadly poison.

Formalin is used at a strength varying from ¼ per cent. to 2 per cent., depending on the time of immersion and the material to be treated. To make a 1 per cent solution, add 1 oz. of formalin to 5 pints of water. Other strengths may be calculated from this. The time of immersion varies as in the case of corrosive sublimate.

For these treatments seed is conveniently handled by tying in cheese-cloth or a similar open material.

A certain amount of seed injury or retardation of germination sometimes follows disinfection. This undesirable result can largely be eliminated by soaking the seeds in water before immersion in the disinfectant, and washing for five to ten minutes in several changes of clean water after treatment. The pre-soaking provides for less absorption of the poisonous fluid into the interior of the seed, while the subsequent washing removes any injurious compound which might continue its action after removal from the main supply. The seed after washing should be spread out to dry, and then sown as soon as possible.

In Europe and America certain organic mercury compounds are now available for seed disinfection which are proving in many cases superior to the chemicals used in the older methods.

Soil Sterilisation.

By far the best method for carrying out soil sterilisation is by means of steam. This is, however, impracticable for the average grower. Small areas of ground such as seed-beds may be sterilised by means of formalin. The beds are prepared ready for planting and then watered with formalin solution of 1 to 2 per cent. strength at the rate of 4 gallons to the square yard. The beds as soon as treated are covered with sacking, &c., for a few days to keep in the fumes, and then after airing for about a week are ready for use.

When diseases such as damping-off make their appearance after planting, the spread may often be checked by the application of a mixture known as Cheshunt compound. It is prepared as follows:—

Two ounces of powdered bluestone (copper sulphate) is mixed thoroughly with 11 oz. of crushed and powdered rock ammonia (carbonate of ammonia). This stock mixture should be kept in a stoppered bottle. It is dissolved in water at the rate of 1 oz. to 2 gallons, and the solution then watered on the soil so as to thoroughly wet it. The solution can be held in wooden or copper vessels only.

CHAPTER VII.

PESTS AND DISEASES OF DECIDUOUS FRUITS.

The first chapter dealing with the actual pests and diseases is devoted to those assocated with the deciduous fruits grown almost exclusively in the Stanthorpe district. With two notable exceptions—namely, the Queensland fruit fly and the Rutherglen bug—all the important enemies of deciduous fruits in this State have been introduced from overseas. The following insects are dealt with in this chapter:—Queensland fruit fly, codling moth, woolly apple aphis, and San José scale. A brief reference is also made to Rutherglen bug, but this serious pest is dealt with in detail elsewhere—namely, in Chapter XIII., which is devoted to general feeders. The diseases discussed in the present chapter are downy mildew, oidium or powdery mildew, and anthracnose or black spot, all attacking grapes; powdery mildew of pome fruits; prune rust, brown rot, black mould rot, and leaf curl attacking various stone fruits.

The Queensland Fruit Fly.

The Queensland fruit fly (*Chætodacus tryoni* Froggatt) is rightly regarded as being worthy of inclusion in the category of highly destructive insects. Records of its occurrence were obtained in the early days of fruit-growing in this State, and for almost forty years it has been a subject of great interest to both fruit-growers and scientific investigators. It has frequently been stated that the Queensland fruit fly is identical with an Indian species, *Dacus ferrugineus* F., but local opinion favours the belief that the fly now under discussion is a native of this country and is not the Indian species referred to. The Queensland fruit fly is not confined to this State, for many records of its occurrence have been obtained in the neighbouring State of New South Wales.

Detailed Investigations.

The following paragraphs contain a brief account of what is at present known with respect to the life history and control of the Queensland fruit fly. The pest was studied by Henry Tryon many years ago, and more recently it has been the subject of a detailed investigation by Hubert Jarvis, the Departmental Entomologist stationed in the Stanthorpe district. Tryon's early reports have long been out of print, but that is not the case with respect to those prepared by Jarvis, and readers who desire fuller details with respect to this pest should accordingly consult the various progress reports published by Jarvis. The Queensland fruit fly has also been extensively studied by F. A. Perkins, who was located at Stanthorpe for several years as Stanthorpe Research

Fellow, working in association with the University of Queensland. A number of progress reports by the latter investigator have appeared in the local press.

Nature of Injury.

The larva or maggot is the life-cycle stage in which this insect damages fruit. The larva feeds voraciously and tunnels throughout the fruit in any direction, and not only does it destroy much tissue in doing so, but its presence also leads to the rotting of the attacked fruit, which is rendered valueless for marketing.

Fruits Attacked.

The fact that the Queensland fruit fly has been a pest of outstanding importance of deciduous fruits grown in the Stanthorpe district has sometimes somewhat obscured the additional fact that it is a species that attacks a wide range of cultivated fruits other than those produced at Stanthorpe.

It has been recorded as attacking the following fruits:—Apple, apricot, banana, cape gooseberry, cherry, custard apple, date, fig, granadilla, grape, grape fruit, loquat, mandarin, mango, nectarine, passion fruit, papaw, orange, peach, pear, persimmon, plum, quince, tomato, and walnut. It has also been bred from quite a number of other fruits, including those of certain native trees.

The Queensland fruit fly attacks bananas in the Southern banana districts, but in the North the fruit fly losses in bananas are due to the presence of another species, namely *Chætodacus musæ* Tryon.

It is rather a curious fact that the notorious Mediterranean fruit fly (*Ceratitis capitata* Wied.) does not occur in this State, although it is a very common species in the neighbouring State of New South Wales.

Life Cycle Stages.

The egg (Plate 6, fig. 1) of the Queensland fruit fly is creamy white in colour and is distinctly elongate. It is slightly curved and tapers at both ends, measuring roughly about $\frac{1}{25}$ inch in length. It might quite appropriately be described as being somewhat banana-shaped.

The larva (Plate 6, fig. 2) is creamy white in colour and measures about $\frac{1}{3}$ inch in length when full-grown. It is bluntly rounded off at the anal end but it tapers off to a fine point at the head end. It is legless but is nevertheless capable of moving over a surface when removed from the fruit, and it is, further, capable of jumping quite appreciable distances.

The pupa is formed within a somewhat hard-shelled yellowish-brown or reddish-brown cylinder, known as the puparium (Plate 6, fig. 3). The puparium is bluntly rounded off at either end and is about $\frac{1}{6}$ inch in length.

The adult (Plate 6, fig. 4) is a rather prettily marked fly, of a somewhat reddish-brown colour broken by numerous conspicuous lemon-yellow spots or lines on the thoracic segments. In the female there is

Chætodacus tryoni Froggatt.

Fig. 1.
Eggs x 10.

Fig. 2.
Larva x 5.

Fig. 3.
Puparium x 5.

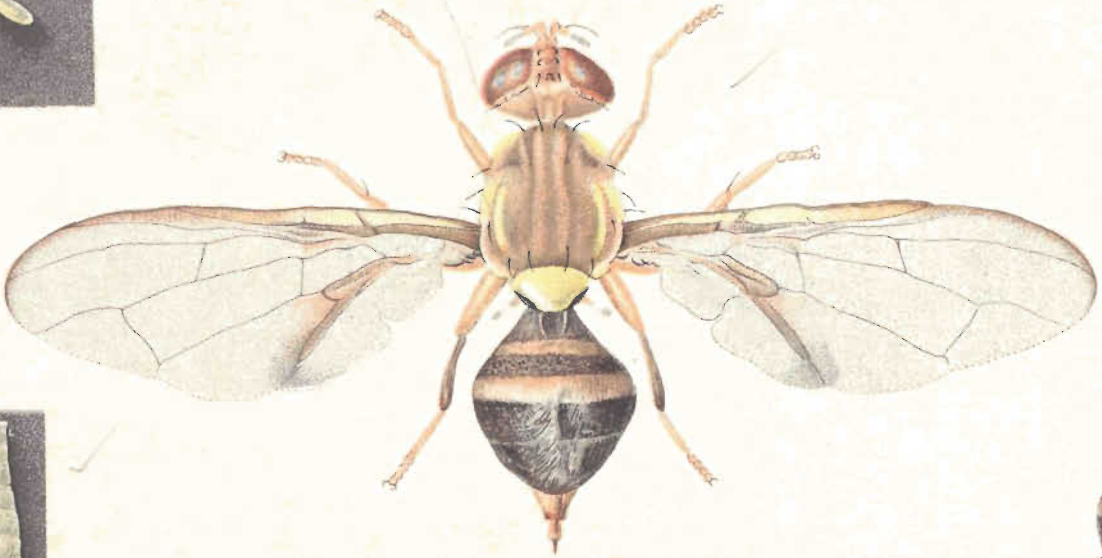


Fig. 4.
Adult x 10.

Fig. 5.
Male Abdomen x 10

by these native enemies is, however, only relatively slight, and hence the orchardist must resort to artificial control measures to check the ravages of this pest and to supplement the efforts of the parasitic and predatory enemies.

CONTROL MEASURES.

The preceding brief outline of the life history of the Queensland fruit fly should clearly indicate the possibility of the successful adoption of certain measures of control. Outstandingly important in the campaign against this pest is the collection and destruction of infested fruit. This measure has been consistently advocated ever since the attention of investigators was first directed to the problem some forty years ago, and it should still be retained as an extremely important means of combating the fruit fly.

Orchard hygiene should therefore be the first line of attack against this pest, and infested fruit should be regularly collected and destroyed. To facilitate the picking up of infested fruit that has fallen to the ground, the orchard should be kept as free from weeds as is practicable. If the orchard is overgrown, then efficient picking up will be a matter of considerable difficulty, and much infested fallen fruit will be overlooked, and the maggots contained therein will leave the fruit, pupate in the soil, and produce a fresh brood of flies.

When the infested fruit has been collected, the question of the best means whereby it may be disposed of automatically arises; the orchardist has the choice of several means of dealing with that fruit, and each of these is quite satisfactory, if properly practised.

One at least is, however, open to serious objection if carelessly carried out, and indeed, when proper precautions are not observed, the labour expended on the collection of the fruit is rendered quite valueless. Here reference is made to the burying of the infested fruit.

Boiling infested fruit that has been picked up is a very effective means of disposal, and is one that is in general favour. Burning the stung fruit in a good hot fire can also be practised, and, as already mentioned, the burying of picked-up fruit is an alternative means of disposal. When the latter practice is followed, every precaution must, however, be taken to ensure that the fruit is buried deeply, i.e., with a soil covering of about 18 inches. If the stung fruit is but slightly covered with soil, no good will have been accomplished by its collection, for large numbers of flies can emerge from infested fruit that has been buried in a shallow trench.

The next control measure to which reference must be made is the reduction of the adult fly population by means of luring. A lure and suitable glass traps are now on the market; where these are employed in an orchard they should be placed on boards in leafy trees and then baited with the fruit-fly lure. It is essential that the traps be placed in the orchard early in the season, and that they receive regular attention for such purposes as the renewal of the lure.

A further control measure of value is the elimination of all useless fruit-trees or other plants that may serve to harbour the fly and to act as a source of infestation in which flies will be bred to attack and destroy the cultivated fruits on which the orchardist is making his living.

The possibility of controlling the Queensland fruit fly by the use of both repellents and poison sprays has not infrequently been a subject of inquiry, but, so far as the entomological branch of this department is concerned, it possesses no definite evidence to show that these measures can as yet be recommended as being both practicable and effective. They are, however, worthy of some further attention, but in the meantime efforts at control should be concentrated on the measures already recommended.

Firstly, collect and destroy infested fruit; secondly, trap the adult fly; and thirdly, eliminate worthless, non-commercial fruit-trees.

The Codling Moth.

The codling moth (*Cydia pomonella* Linn.) is without doubt one of the most serious pests of the apple in Queensland, and the losses due to its destructive activities are surpassed only by those inflicted by the Queensland fruit fly. Elsewhere the codling moth is generally regarded as the worst insect pest known to the apple-grower.

It is believed that this pest is a native of South-eastern Europe, whence it has spread to every other continent, and it is safe to say that there are few districts in which apples are grown that are not now thoroughly infested. The Stanthorpe district of Queensland is unfortunately included in the infested areas. It is somewhat difficult to say just when the codling moth reached Queensland, but records show that infested fruit was observed in Brisbane in 1889. Much earlier references to this pest are available in the Southern States, and a severe infestation was recorded in Tasmania as far back as 1857.

The word "codling" is, in the opinion of some investigators, merely a corruption of the old English word "querdlying," a term that was employed to signify a half-grown or immature apple. It has also been employed in more recent years to designate a number of varieties of cooking apples.

The "wormy" apples produced by the feeding of the codling moth larvæ have been referred to in European publications for centuries, and a reference to "wormy apples" occurs even as early as 200 B.C. in Cato's treatise on agriculture.

The codling moth belongs to the family Tortricidæ in the order Lepidoptera, and is very closely allied to several species that also live in fruits and seeds, e.g. the nut fruit tortrix (*Carpocapsa splendidana* Hb.), which attacks the fruits of Spanish chestnuts in Europe.

Nature of Injury.

The injury, as is the case with practically all species of destructive moths, is inflicted in the immature stage known as the larva or caterpillar, the moth itself being quite incapable of attacking the fruit. The larva, on hatching from the egg laid by the moth, enters the fruit and eats its way through the flesh to the core. There it continues feeding, and in doing so it scoops out an irregular cavity and also feeds on the pips. Much of the attacked fruit falls to the ground while still small and green, and is obviously quite unmarketable.

Fruits Attacked.

The apple is pre-eminently the fruit that is severely attacked by the codling moth, although very appreciable losses may also occur in pears, quinces, and walnuts. The peach, nectarine, plum, apricot, and cherry have also been recorded as host fruits of this pest.

Life Cycle Stages.

The egg (Plate 7, fig. 1) of the codling moth is somewhat oval in outline, and is about the size of a small pin's head. It is a very thin, semi-transparent object, and has been rather aptly described as resembling a fish-scale. When just laid the egg is pearly white in colour, but as the incubation period advances a red ring develops which tends to give it a darker appearance. An examination with a hand lens will show that its surface, particularly round the flange, possesses a beautifully sculptured network of ridges.

The larva (Plate 7, fig. 2), when full-grown, is about ¾ inch in length, and is pinkish or whitish in colour, with a brown head and a number of scattered hairs on the body. It possesses eight pairs of legs, three of these being jointed legs situated on the thoracic segments, while the remaining five pairs are fleshy unjointed legs situated on the abdominal segments.

The pupa or chrysalis (Plate 7, fig. 4) is brown in colour, and measures about ½ inch in length. The head, eyes, antennæ, and legs of the future moth can be distinctly seen in the pupa.

The moth (Plate 7, figs. 5, 6) measures about ¾ inch when its wings are spread out, as in fig. 5 of Plate 7). The front wings are grey in colour, but the uniformity thereof is broken by a number of irregular darker transverse lines, and is further modified by a patch of beautiful copper-coloured scales of a metallic tint. The hind wings are a plain greyish-brown colour.

Life History.

The codling moth passes through the winter months as a larva in a tough silken cocoon (Plate 7, fig. 3), and the stock of codling moth available for starting the infestation each season on the orchard consists of such larvæ as have survived the winter in safe situations.

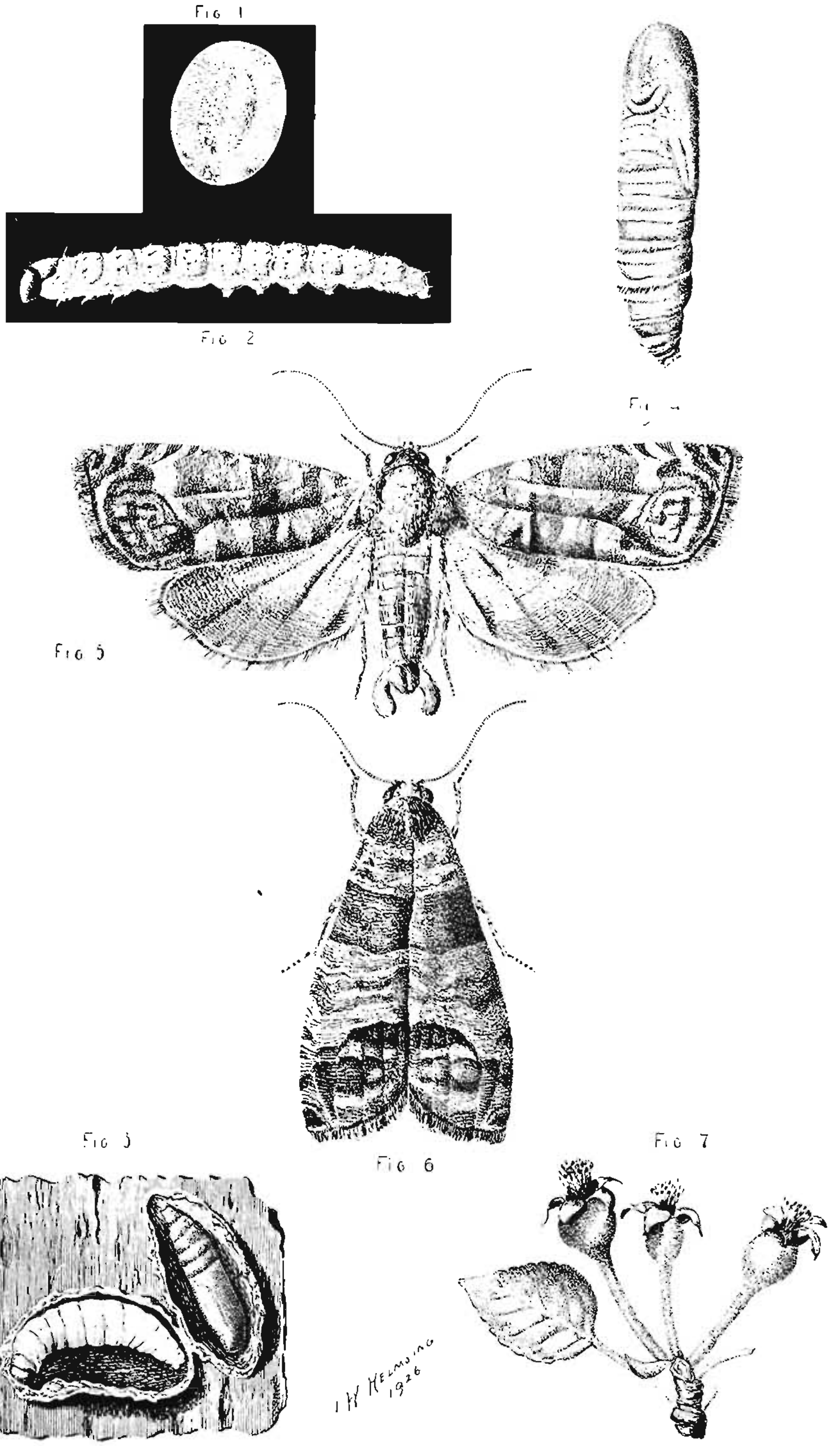


Plate 7.—The Codling Moth (*Cydia pomonella* Linnæus).

Fig. 1.—Egg of codling moth × 15.
Fig. 2.—Larva × 4.
Fig. 3.—Larva and pupa in silken cocoons × 2.
Fig. 4.—Pupa × 4.
Fig. 5.—Moth or imago with wings spread × 5.
Fig. 6.—Moth or imago with wings folded × 5
Fig. 7.—Correct time for first spray.

At the approach of spring these overwintering larvæ transform to pupæ, and in the pupal stage profound reorganisation takes place, as a result of which the moths emerge after a pupal period of about three or four weeks under average conditions.

Many of the moths developed from the overwintering larvæ emerge a few days after the petals have commenced falling from the apple blossoms, and after mating they proceed to lay their eggs. These are laid mainly on the leaves in the case of the spring brood moths at present under consideration, and after an incubation period of about ten days the young larvæ hatch out.

The young larvæ may feed for a short period on the young foliage, but they generally make for the fruit and enter it usually at the calyx or flower end in the case of this first generation. In the later generations, however, many of the larvæ enter at the side of the fruit, particularly where two fruits touch. The larvæ having entered the fruit then work their way to the core, and feed as already indicated in an earlier paragraph. The larvæ of the first generation are generally full-fed in slightly less than four weeks, at the end of which period they leave the fruit and go in search of a suitable spot in which to pupate.

The pupæ are found under pieces of loose rough bark or in cavities or cracks in the limbs of the tree; pupation may also take place under clods of earth at the base of the tree, and in fact in many other situations. The duration of the pupal stage in the first generation, like that of all other life-cycle stages, varies appreciably, but it is generally about twelve or thirteen days, which is very much shorter than in the case of the pupæ formed by the overwintering larvæ.

At the end of the pupal stage the moths emerge, feed, and mate, and in three or four days after mating the females start egg-laying, thus commencing the next or second generation.

There is usually only one brood of codling moth each year in England and in Northern Europe, but in Queensland two generations occur regularly, and a third is quite possible.

Control Measures.

The following control measures are available for combating this pest:—

(1) Spraying with arsenate of lead;
(2) Bandaging of trees;
(3) Destruction of windfalls;
(4) Cleaning up packing sheds;
(5) Cleaning bark of infested trees;
(6) Judicious thinning of heavy crops.

While each of these control measures is undoubtedly productive of much good, no one of them will alone give thoroughly effective control. It is therefore strongly recommended that all six measures be enforced, and if

that is done there is every reason to believe that in a normal season losses will be reduced to relatively small proportions.

Spraying with arsenate of lead must be repeated several times, and the first spray should be applied as soon as the petals have fallen and before the calyx-cup has closed. The lobes or sepals of the calyx are wide apart for about a fortnight after the fall of the petals, and a spray applied before these lobes close up coats the calyx-cup with the poison. As already mentioned in the discussion of the life history of this pest, the great majority of the larvæ of the first generation enter at the calyx end of the fruit, and in doing so they are poisoned by the arsenate of lead which they swallow when eating their way in at the calyx. The correct time at which to apply the calyx spray is indicated in figure 7 of Plate 7.

The mortality among the young larvæ is by no means exclusively caused by their attempting to enter at the poisoned calyx, for observations have shown that many perish before reaching that portion of the fruit. Earlier remarks indicated that many of these larvæ feed for a brief period on the tissue of the leaves on which they hatch out, and in doing so they will in many cases swallow fatal doses of the arsenate of lead with which the foliage is coated.

The calyx spray is of great importance in the control of this pest, and it should invariably be applied. It must, however, be succeeded by several cover sprays at intervals of two or three weeks, the object of these sprays being to coat the growing apple with poison.

The strength at which the arsenate of lead is applied varies to some extent, some investigators recommending 1 lb. of the powder arsenate of lead to 50 gallons of water, or 2 lb. of the paste arsenate of lead to a similar quantity of water. Other workers recommend sprays that are 50 per cent. stronger—i.e., 1½ lb. of powder arsenate of lead to 50 gallons of water. The weaker strength is that at present recommended in Queensland.

No matter how carefully spraying may have been attended to, an appreciable proportion of young codling moth larvæ will escape poisoning, and hence spraying must be supplemented by other control measures.

The bandaging of trees is one of these important supplementary control measures, and its adoption is definitely recommended. It will be found that many of the larvæ, on leaving the fruit to locate suitable spots for pupation, assemble under the bands, and if these are periodically examined at intervals of a week the insects found thereunder can be destroyed. The success of this control measure will largely depend on the trees having previously been cleaned of cover under which the larvæ might otherwise wish to pupate, e.g. under pieces of loose bark. The bandages can be made from a piece of strong cloth 10 inches wide, which is folded to form a double band 5 inches wide, and is then bound tightly round the tree and held in position by a nail. It is recommended that in the Stanthorpe district bandages be in place on the trees at the end of October.

The destruction of windfalls is another important measure of value in reducing codling moth infestation. If windfalls attacked by codling moth larvæ are allowed to remain on the ground, many of the larvæ contained therein will survive and complete their development, thus still further intensifying the infestation.

The cleaning up of packing sheds is a valuable precaution that should not be overlooked, because many of the larvæ in infested fruit leave the fruit when in the packing sheds and select suitable crevices in which to spin their cocoons and overwinter. The flooring boards, packing benches, and empty cases should therefore be carefully inspected, and, if necessary, treated with boiling water in an endeavour to kill any larvæ that may have taken shelter therein.

Mention has already been made of the fact that, in bandaging, success will be most marked when the banded trees are thoroughly cleaned up, so as to eliminate shelter spots to which the larvæ may go for pupation in preference to assembling under the bands. For this reason it is highly desirable to close up any cavities or cracks that may occur on the branches or main stem of the trees, and also to scrape off any loose bark that may be present. For the former purpose sticky clay or putty is satisfactory, and for the latter any suitable blunt instrument may be used.

Finally some reference must be made to the fact that the thinning of fruit, where a heavy crop of apples has set, is of some material advantage so far as codling moth control is concerned. A judiciously thinned crop can be sprayed in a much more satisfactory manner than one that has not been so treated.

Prominence has recently been given to the trapping of the moths themselves in glass containers baited with suitable attractants. This possible method of control was tested fairly extensively during the 1926-27 season in the Stanthorpe district, but the results obtained, under the conditions then prevailing in that district, were very disappointing, and trapping of the moths cannot be added to the list of control measures.

Reference must also be made to the present attempt to establish some measure of biological control. This originated in September 1927, when a colony of a very small wasp, *Trichogramma minutum* Riley, was received from California. This beneficial insect attacks the eggs of the codling moth, and when Mr. Ranger, manager of the Committee of Direction of Fruit Marketing, was in North America last year he saw the handling of this parasite by Mr. Flanders, the entomologist of the Walnut Growers' Association. Mr. Ranger was much impressed by that work, and accordingly arrangements were made to forward a colony of the parasite to Queensland. It has since been bred in Brisbane and liberated in the orchards. This is not an attempt to introduce a new

parasite, the object being to artificially increase the numbers of an already established insect, thus transforming a rare species into a valuable control factor.

To summarise the control measures:—Spray with arsenate of lead, commencing with a calyx spray as soon as the petals have fallen, following thereon with several cover sprays; bandage the trees and examine regularly and destroy the larvæ assembled under the bands; destroy all windfalls; thoroughly clean the packing sheds; scrape loose bark from trees and fill up all cracks and crevices thereon; judiciously thin out heavy crops of fruit.

The Woolly Apple Aphis.

The two preceding pests just dealt with in this chapter, namely, the Queensland fruit fly and the codling moth, have every reason to be regarded as the two most important apple pests in this State. The one now under consideration is, however, a close competitor for inclusion in the category of highly destructive enemies of the apple. Like the codling moth, it has gradually become widely distributed throughout the world, and there are probably few regions in which apple-growing is now unaccompanied by its very unwelcome presence and associated losses.

The woolly apple aphis (*Eriosoma lanigerum* Hausm.) belongs to the family Aphididæ in the order Hemiptera. The popular name just quoted is that under which it has long been known in Australia, but in England it is very frequently referred to as American blight, while on the continent of Europe it is often spoken of as the blood-louse. The name blood-louse has been suggested by the stain left when the bodies of this aphis are crushed in the hand.

This pest is certainly not a native of Australia, and it would appear that either North America or Europe must accept the somewhat unwelcome responsibility for having presented it to the apple-growers of the world. It was described in Europe by Hausmann in 1802, but according to French, of Victoria, there are records of its occurrence in England as far back as 1789. The same authority also states that it is said to have occurred in Victoria as early as 1849.

Nature of Injury.

The woolly aphis feeds by means of the piercing mouth parts which characterise the order of insects to which it belongs, and as a result of its feeding activities very typical gall-like malformations (Plate 8, fig. 4) are produced on the infested branches and roots, for this pest works both under ground and above ground.

It characteristically feeds in colonies and the injurious effects produced by the constant feeding of large numbers of aphids on the branches and roots must obviously be very prejudicial to the welfare of the tree. Not only is the vitality of the tree reduced by the removal of its sap, but, as a reaction to infestation, the typical deformities already

mentioned are produced. While infestation may be a serious matter in trees of any age, it may even be fatal in its results on young stock. It is frequently claimed that the underground colonies of this pest feeding on the root system produce a far more prejudicial effect on the tree's vitality than the more conspicuous colonies feeding on the branches.

PLANTS ATTACKED.

Among cultivated fruits the apple is outstanding as the host plant of this pest. Infestation of pear, quince, and plum has also been recorded, but such occurrences are so extremely rare that the pest might almost be described as exclusively an apple insect at least so far as the orchardist is affected by its presence. This, however, would not be true so far as trees in general are concerned, for in the course of a detailed study of the life history of this pest in North America it was shown that it winters on the elm-trees. The mountain ash and hawthorn are also attacked in the United States.

THE APHIS.

This species of aphis is characterised by a copious secretion of wax which is deposited as a powdery bluish-white substance over the surface of the body. There is, in addition, a secretion of long waxy threads or filaments, which in the branch-feeding colonies are white and fluffy; hence the popular Australian name woolly apple aphis. These threads also occur in the root-feeding colonies, but they are there of a somewhat bluish-white tinge rather than the pure white colour so typical of the branch-inhabiting individuals.

A close examination of these white woolly masses will show that they merely screen a large number of small oval aphids which have been variously described as being dull purplish brown, slaty blue, or plum-coloured.

The life history of this species has been studied in very considerable detail in the United States, but, so far as is known, it has received but little attention in this country.

CONTROL MEASURES.

The control of the woolly apple aphis has been attempted along three distinct lines, and at the present moment it can be claimed that, in the Stanthorpe district, these three types of control measures constitute between them a very effective check upon this potentially destructive insect.

The first of the control measures referred to is the selection of trees that will be resistant to the attacks of this pest at least on the root system. This was successfully accomplished many years ago, and it has long been the practice to work apples on a stock that has shown resistance or immunity to infestation. For this purpose the Northern Spy and the Winter Majetin have been largely availed of. If the trees are worked on these blight-resistant stocks, then the orchardist need not

worry about infestation on the root system, and he can concentrate his attention on the infestation on the branches. This success in eliminating the underground colonies of the aphis constituted a very marked advance in the direction of achieving effective control.

For the control of the branch infestation spraying has been much in favour, nicotine sulphate being employed in summer and oil sprays in winter. To effectively control these above-ground colonies the nicotine sulphate should be sprayed under high pressure close to the infested limbs, so that a drenching spray is produced and the insects thus effectively reached. The oil sprays may be used in winter, but they cannot be employed with the drenching effect referred to in the application of the nicotine sulphate sprays, otherwise excessive and injurious quantities of the oil sprays will collect at the butts of the treated trees. However, if the spraying with nicotine sulphate has been satisfactorily performed in summer and autumn, only a mist-like spray will be necessary in the case of a winter application of a miscible oil. Unfortunately, repeated spraying with nicotine sulphate is necessary for the control of the branch-infesting colonies of this pest during summer and autumn. The orchardist is particularly busy at that time of the year, and hence the necessity for frequent spraying imposes a heavy burden not only on his pocket but on his time, which is so urgently required for other operations on the orchard. The employment of a third type of control measure has, however, very materially reduced the burden of spraying; in fact, it has at present largely but not completely eliminated the necessity for doing so. Long may that continue to be the case.

The third line along which control has been attempted is the utilisation of the services of natural enemies—i.e., the biological control method. Much has been written of late years on this subject, and some strikingly successful results have been obtained in its application. One must never, however, lose sight of the fact that the prospects of success warrant the expenditure of time and money on this control measure in only a comparatively limited number of problems. However, in the case of woolly apple aphis infestation in the Stanthorpe district it appears to have justified itself in a highly gratifying manner.

The attempt at biological control commenced in 1923 when a colony of a small wasp parasite, *Aphelinus mali* Hald. (Plate 8, fig. 3), was obtained from New Zealand by Hubert Jarvis. This parasite is a native of North America, whence it had been introduced to the former country by the officers of the Cawthron Institute.

The parasite in question is a typical Chalcid wasp measuring about $\frac{1}{25}$ inch in length. It lays its eggs in the bodies of the woolly apple aphis, and the larvæ (Plate 8, fig. 1), hatching from these eggs, feed on the body contents of the destructive insects. When full-grown, the parasite larvæ transform to pupæ (Plate 8, fig. 2) within the woolly aphids, which are by that time dead and consist merely of hard empty shells.

Fig 4

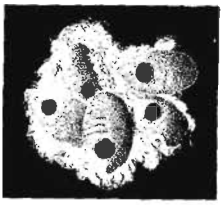


Fig 5

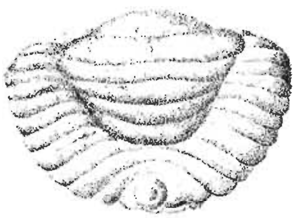


Fig 1

Fig 2

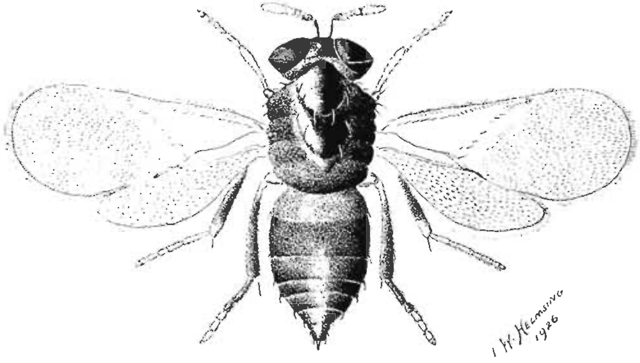


Fig 3

Plate 8.—The Woolly Aphis Parasite (*Aphelinus mali* Hald.).

Fig. 1.—Larva of *Aphelinus mali* × 40.
Fig. 2.—Pupa of *Aphelinus mali* × 40.
Fig. 3.—Imago or adult of *Aphelinus mali* × 30.
Fig. 4.—Twig showing parasitized and unparasitized woolly aphis, all those on the lower colony being parasitized, whereas only a few on the lower edge of the upper colony have been attacked. Natural size.
Fig. 5.—Aphis showing the emergence holes of *Aphelinus mali* × 6.

In this stage the body contents of the parasites are completely reorganised and the adult wasps are produced. These emerge by cutting circular holes in the shells of their dead hosts (Plate 8, fig. 5).

As already indicated, this introduction has been very successful and has materially reduced the cost of controlling woolly apple aphis.

The San José Scale.

The San José scale (*Aspidiotus perniciosus* Comstock) is probably one of the most widely known of the many pests attacking deciduous fruit-trees. Furthermore it is conspicuous among the most destructive of the numerous scale insect pests. It first acquired notoriety in the San José district of California some fifty or sixty years ago, hence the name by which it is popularly known. It is believed to be a native of China, whence it was unfortunately imported to California. This undesirable immigrant is thought to have reached Australia in 1894.

Nature of Injury.

This pest attacks the trunk, branches, leaves, and fruit of infested trees (Plate 9, figs. 8, 9, 10), and a characteristic reddish or pink discolouration is usually associated with its presence wherever it is feeding on the plant tissue. If immediate steps are not taken to deal with the pest when it shows up in an orchard, the infestation increases with quite extraordinary rapidity, and may become sufficiently acute to eventually kill the attacked trees. This insect, like all other species of scale insects, feeds by sucking the plant sap, and the opinion has been expressed that it has a more prejudicial effect on its host plant than any other scale insect attacking fruit-trees.

Plants Attacked.

The San José scale has a very wide range of food plants, and among the deciduous fruit-trees attacked mention may be made of the following:—Apple, apricot, cherry, peach, pear, plum, prune, and quince.

Life Cycle Stages.

The female scale when full-grown (Plate 9, fig. 6) is roughly about the size of a pin-head, and is almost circular in outline and is slightly convex. The scale itself is a greyish-brown colour, and is merely a waxy secretion with incorporated moulted skins which covers and protects the actual insect underneath. The soft-bodied yellowish insect (Plate 9, fig. 5) is circular in shape and is legless.

The male scale (Plate 9, fig. 7) is smaller than the female scale, and is somewhat different in shape, being distinctly more elongate. The adult male insect (Plate 9, fig. 3) is totally different from the female, and is a small delicate insect provided with a single pair of wings.

The young scale insects (Plate 9, fig. 1) are lemon yellow in colour, and possess three pairs of legs. They are very small, and can just be seen with the naked eye.

Life History.

The males and females mate, and several weeks after mating the females commence to give birth to living young, as many as several hundreds being frequently produced by a single female. The small lemon-yellow young or larva leaves the protection of the mother scale and crawls over the tree in search of a suitable spot at which to settle down. Having found such a spot, which is generally obtained in a few hours, the young insect inserts its long, thin, threadlike, piercing mouth parts into the plant tissue and commences sucking the sap. The body gradually becomes covered with waxy threads, and eventually the typical protective scale is produced. The young insects moult in about a fortnight, and they then lose their legs. The males undergo two more moults and then emerge as delicate two-winged insects. The females moult a second time and remain legless, wingless insects. They then mate with the males and subsequently commence to produce living young. Definite figures with respect to the number of generations produced each year in Queensland are not available, but in North America it is believed that three or even four may be produced each year. Bearing in mind this fact, coupled with the rate of production of young per female, it is not difficult to understand that, where this pest is neglected, infestation may rapidly become so serious that the bark is smothered in a mass of scales which give it a greyish scurfy appearance.

Control Measures.

San José scale in a well-established orchard can be quite effectively controlled by spraying during the winter months, using either lime sulphur or miscible oils. If only a few infested trees occur in a very young orchard, it is probably worth while to destroy these trees in the hope of exterminating the pest for the time being, although sooner or later the pest will come in from neighbouring orchards. Nursery stock should be fumigated to destroy any scale insects that may be present.

The Rutherglen Bug.

The Rutherglen Bug (*Nysius sp.*) appears in epidemic form every few years in Australia, and when it does so it inflicts very severe damage in deciduous fruit orchards. Such an epidemic occurred in the spring of 1926 and continued into early summer. This pest, which is extremely difficult to deal with, is a general feeder, and a detailed discussion of its life history and control is accordingly reserved for Chapter XIII.

Downy Mildew of Grape Vine.

Downy mildew is the most serious disease with which grape-growers have to contend. It is now distributed throughout practically all the chief vine-growing centres of the New and Old Worlds wherever climatic conditions are suited to its development. Australia was fortunate in being one of the last countries to be visited by this disease, which only

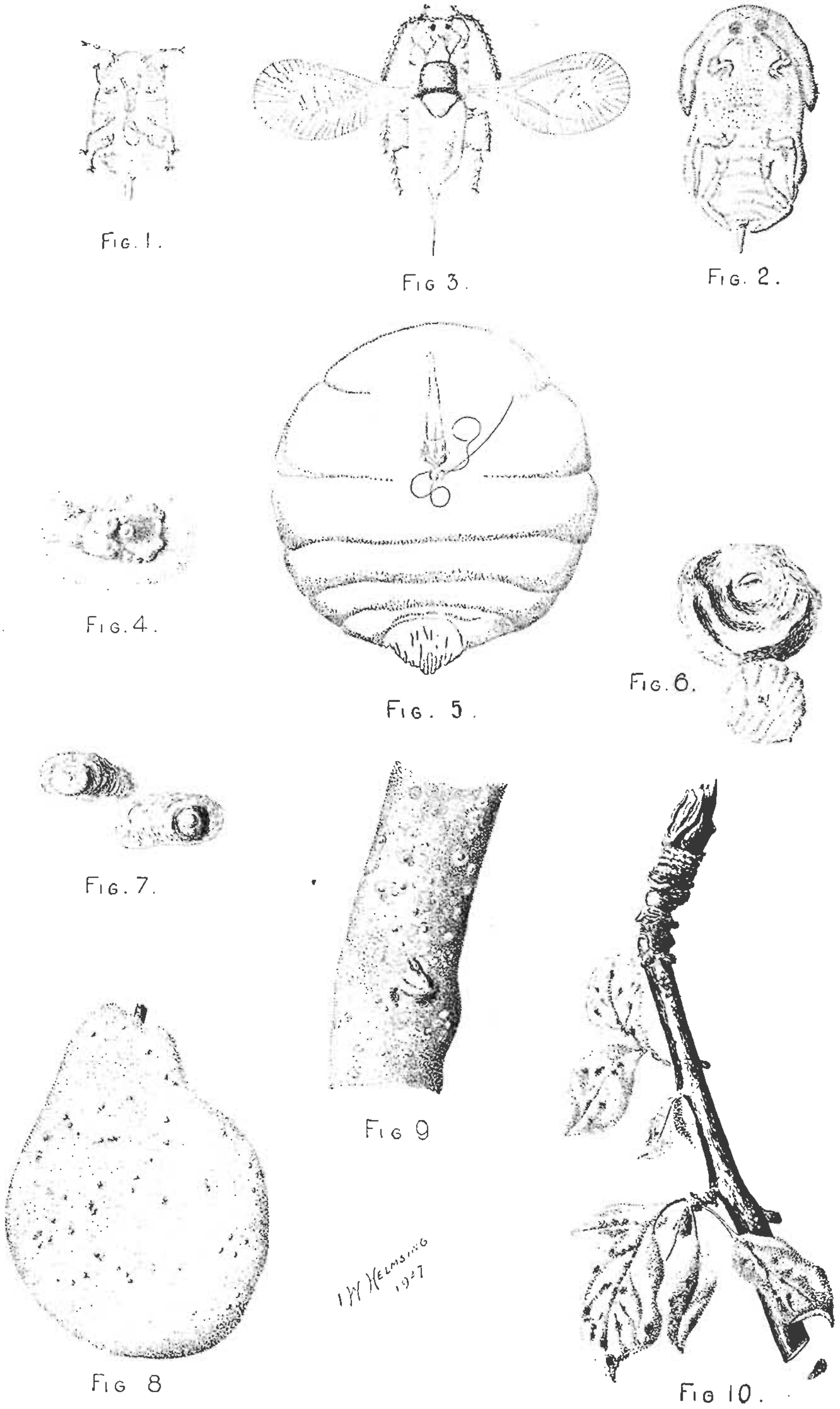


Plate 9.—The San José Scale (*Aspidiotus perniciosus* Comstock).

Fig. 1.—Young larva × 57.
Fig. 2.—Pupa of male × 57.
Fig. 3.—Adult male × 32.
Fig. 4.—Colony of scales in various stages of development × 4.
Fig. 5.—Adult female × 32.
Fig. 6.—Adult female scale turned over to reveal the insect itself × 12.
Fig. 7.—Male scales × 12.
Fig. 8.—Pear fruit, showing infestation.
Fig. 9.—Apple twig, showing infestation.

appeared in epidemic form during the 1917-18 growing season. The malady is one which can be effectively controlled by the application of a fungicide, and hence spraying has become a matter of general routine with all efficient growers except in the drier centres of the State.

Symptoms.

All parts of the vine, including stems, leaves, and bunches, may be attacked in their younger stages. As the tissues mature they become less susceptible to infection. On the leaf the first symptoms appear as light greenish-yellow spots of a roughly circular or sometimes angular shape. When held up to the light these will be seen to be of a clearer and more transparent appearance, giving rise to the name of "oil-spot" which is applied to this stage. If the weather is moist, a delicate white downy growth will be produced on the under surface of the spots as the fruiting bodies of the fungus causing the disease are developed (Plate 13, fig. 1). During hot and dry conditions the fructification will not take place, and the spot turns brown and dries out. By coalescence of the spots large areas of the leaf surface may be affected. The presence of even a small amount of dead tissue may cause distortion of the developing leaf. Affected leaves usually fall off prematurely.

The fruit may be attacked at any period of its development until it commences to colour. When infected during the early stages of growth the bunch usually becomes covered with a downy fungus growth, which has suggested the name of "grey mould" for this particular form of attack. If the berry is approaching maturity the mould is rarely produced. In either case the fruit eventually becomes brown and shrunken and dries up (Plate 13, fig. 1).

Cause.

The disease is due to a fungus (*Plasmopara viticola*) belonging to the Peronosporaceæ or downy mildew group, from which are derived many very important plant parasites. When infection has taken place the fungal threads or mycelium ramify between the cells of the plant tissue, absorbing nourishment from these by means of short haustorial branches. After an incubation period of about seven days, during which a definite oil-spot has been formed, the parasite is in a condition to produce its fruiting stage should the right weather conditions be available. Spore formation will take place readily at a temperature from about 60 to 80 deg. Fahr., provided abundant moisture is present. Short aerial hyphæ grow out four to eight together through the openings of the stomata or breathing pores found on the lower surface. These branch and rebranch, forming a tree-like growth, and from each of the ultimate short peg-like branches there is developed a delicate thin-walled ovate spore. These spores are produced in countless numbers, and, being easily carried about by wind and rain, serve to spread the disease during the growing season. Should a spore be deposited on a leaf when moisture in the form of dew or raindrops is present, its contents will divide up

into several smaller portions, each provided with two thread-like vibratile flagella. These motile structures are known as zoospores (Plate 3, fig. 1D). They escape by rupture of the parent cell or sporangium, and make their way through the film of surface moisture to one of the breathing pores of the leaf, by means of which opening they gain access to the plant.

The summer spores are delicate in structure and are unable to live over from one season to the next. For this latter purpose the fungus is provided with a thick-walled resistant spore known as the oospore. These are formed towards the end of the season within the tissue of the leaf, and remain associated with the rotting foliage during the winter. In the spring, if the weather is sufficiently wet to give rise to a certain amount of water accumulation round the vines, the oospore will germinate in this and give rise to a sporangium which produces zoospores as in the case of the summer spores described above. If another shower should fall and splash the zoospores on the foliage, the infection for the season will be commenced.

CONTROL.

Consideration of the life history of the organism briefly outlined above will show that for a severe outbreak of downy mildew there is necessary a certain temperature combined with abundant moisture. The temperature during the Queensland season, except on abnormally hot days, is quite suitable for mildew development. Rain during the early part of the season in sufficient quantity to provide the necessary moisture requirements for the starting of an attack is always of likely occurrence, while the summer rains provide ideal conditions for its epidemic development. Hence any grower who wishes to make certain of his crop should be prepared to carry out the undermentioned spraying programme, which has been proved to give adequate protection from the disease. It should be noted that the spray to be effective *must* be present on the leaves before the germination of the spores. Once the fungus has penetrated within the tissues of the plant all attempts to stop its development will be fruitless.

Bordeaux (6-4-40) and Burgundy (6-8-40) are the spraying mixtures commonly used, the advantages lying with the former. Applications should be made as follows:—

(1) As soon as the shoots have reached a few inches in length;

(2) Just before the flowering period:

(3) As soon as the young fruit has set;

(4) Additional applications will depend on weather conditions.

If this is at all wet the vines should be sprayed as often as necessary to keep the foliage well covered. Some growers make it a practice to spray once a week throughout the season until the fruit is coloured.

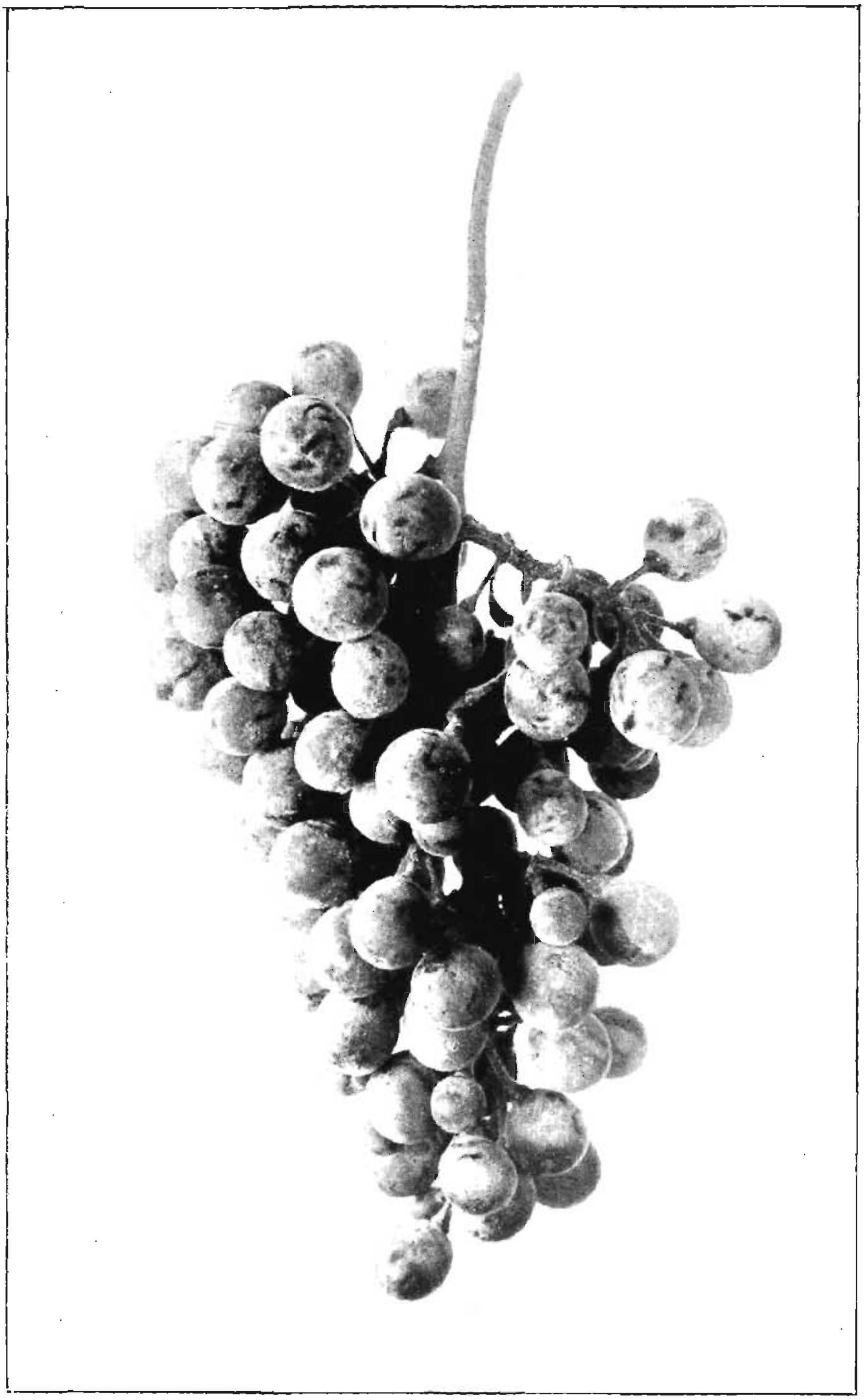


Plate 10.—Oidium of the Grape.

Oidium or Powdery Mildew of Grape Vine.

Powdery mildew is a disease that has been in Queensland for many years and is quite familiar to most growers. All the younger green parts of the vine, including leaves, canes, and fruit, may be attacked, the damage done depending very largely upon weather conditions. Warm and moist but not necessarily wet weather is most suitable to the development of Oidium.

Symptoms.

On the leaf the fungus appears as greyish-white floury patches on the upper and lower surfaces but more conspicuous on the former. This can usually be easily distinguished from the more elevated downy growth found on the under surface of leaves attacked by downy mildew. The white powdery covering may also develop on the young shoots and the canes. This attack will result in a cessation of growth, and if the part is in the immature developing stage deformation may take place.

The most severe damage takes place when the bunch is affected. If this happens before or shortly after flowering, the flowers and small developing fruit which become covered with the mildew soon dry up and drop off. When older fruit becomes mildewed the growth of the skin is retarded and splitting often occurs. Their appearance is greatly impaired even when this cracking does not take place. (Plate 10.)

The retarding effect of powdery mildew on the growth of the vines during one season will cause a reduction in the quantity and quality of the crop the following year.

Cause.

Powdery mildew is caused by a fungus parasite now known as *Uncinula spiralis.* The form in which this organism is commonly met with was first described under the name *Oidium Tuckeri*—hence the common name of Oidium. Later a second and higher form of the fungus was discovered which necessitated the change to the above.

This fungus differs from the organism causing downy mildew in that it belongs to the ectoparasitic type. This difference should be noted since it is of special importance when considering control measures. The fungus grows entirely on the outside of its host, where the mycelial threads form a fine white web-like growth over the affected parts. From the surface mycelium small knob-like processes or haustoria are given off which penetrate the epidermal cells and from them absorb nourishment. The injury done to the plant cells in this way gives rise to dark specklings on the surface of the region affected.

If the weather is warm and moist the fungus will soon proceed to the formation of the fruiting stage. Short upright branches are given off which cut off in succession three or four clear oval spores. (Plate 4, fig. A indicates the type of growth in the powdery mildews.) These spores serve to spread the disease during summer. They germinate by producing a delicate thread-like germ-tube which commences a superficial growth over the plant surface as before. Oidium spores need for their

germination only a sufficiently moist atmosphere to prevent desiccation. The water film so necessary for the zoospores of downy mildew need not be present.

Besides this summer spore a resting spore is produced towards the close of the season. It is of a type which places the fungus in the large group known as the Ascomycetes or sac fungi. This reproductive body consists of a minute rounded structure appearing as a black speck on the leaf surface. Radiating from the surface of these perithecia, as they are called, are a number of appendages, while within are contained about six sac-like cells or asci each containing four to six ascospores. (Compare Plate 5, fig. 3A.) The ascospores reach the foliage in the spring and commence the new season's infection.

In some countries, of which Queensland is one, the ascospore stage does not appear to occur except perhaps rarely, and it is possible that in this case the fungus overwinters by means of summer spores and mycelium hibernating among the dormant buds of the vine.

CONTROL.

On account of the ectoparasitic nature of the causal fungus one is able actually to cure as well as prevent an attack of powdery mildew. Sulphur applied in the form of a dust will cause the death of the superficial mycelium and spores.

Application should be made as follows:—

(1) When the new shoots are about 12 inches long.

(2) When the vines are in flower. In addition to protecting the young fruit, sulphur applied at this time has an exceedingly beneficial action on the setting of the grapes.

(3) Further applications should be made whenever the disease shows signs of development.

Sulphuring is best done on a warm day, but an application during exceptionally hot weather should be avoided, as some foliage-burning may occur under these conditions.

Anthracnose or Black Spot of Grape Vine.

Anthracnose is a disease which does not often appear in the epidemic form which may be assumed by the two mildews; nevertheless, during wet seasons considerable damage may result from its presence in individual vineyards.

SYMPTOMS.

The disease makes its appearance on the early spring growth. The young leaves, tendrils, and shoots develop black patches of dead tissue which lead to a stunting and distortion of the expanding organs. The most characteristic symptoms are displayed by the lesions on the canes.

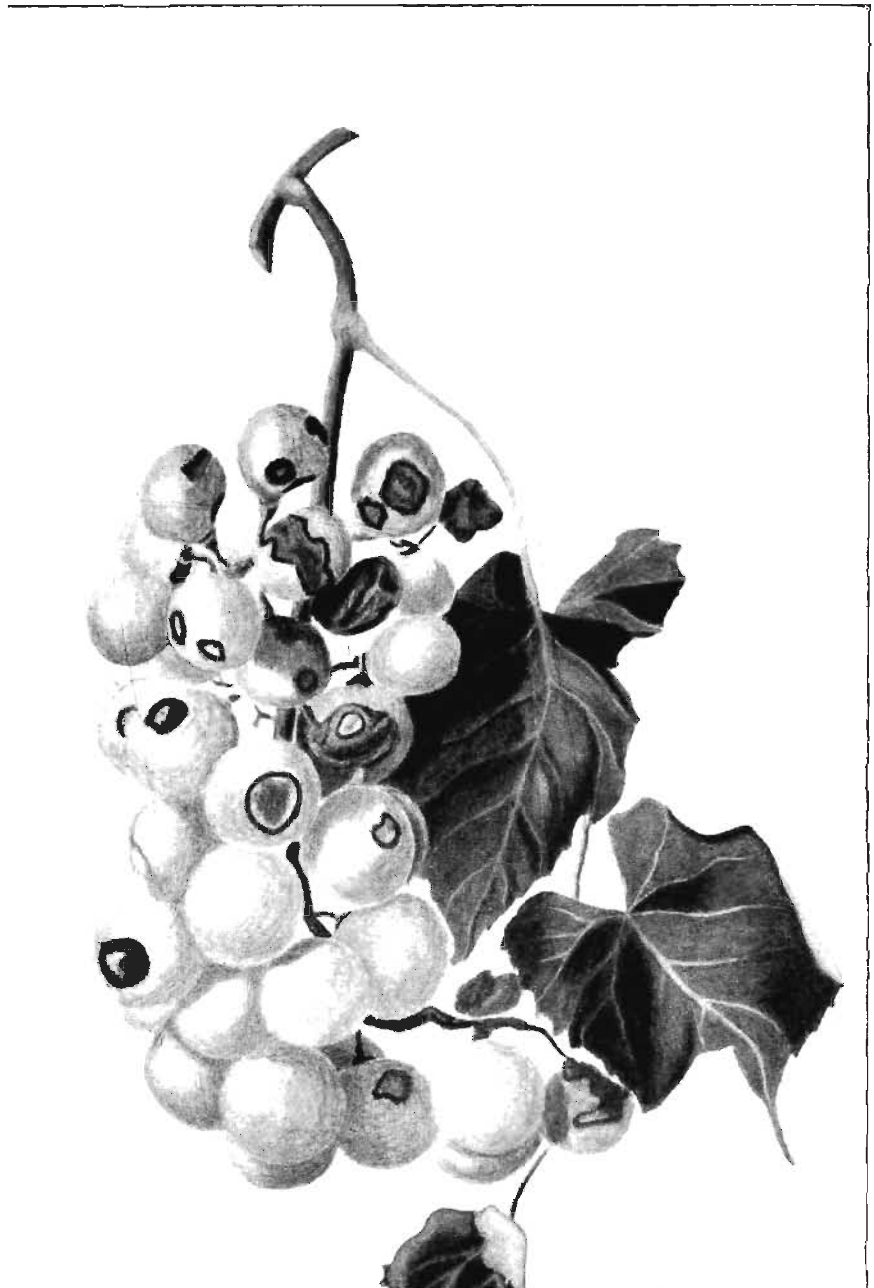


Plate 11.—Anthracnose of the Grape.

These appear first as small dark-brown or black spots. The fungus responsible for their development extends through the tissue both radially and in towards the pith, breaking down the plant cells in its progress, with the result that a more or less conspicuous open black scar or canker is produced. (Plate 12, fig. 2.)

If the bunch is affected in its early stages it may be reduced by destruction of flowers and fruit to nothing more than the blackened and withered fruit-stalks. When older berries are attacked a bird's-eye spotting results. The spots are slightly depressed circular areas having a greyish-pink centre surrounded by a dark-brown to black margin. (Plate 11.) Besides the unsightly appearance, the hardening of the skin may cause splitting to take place.

Cause.

Anthracnose of the grape is due to the attack of a fungus (*Manginia ampelina*) which resembles in general characters the one responsible for bean anthracnose (Plate 5, fig. 8). Spore formation takes place in the base of the cankers and on the fruit-spots, where the spores in mass give a greyish-pink appearance to the affected area. Clusters of short upright hyphæ arising from beds of interwoven fungal threads cut off from their tips numerous clear oval spores. These tend to stick together in mass, so that spore dispersal and spread of the disease is not so rapid as in the case of the mildews.

The fungus overwinters principally in a vegetative form in old scars. Towards autumn the fungal threads become massed together in the more superficial regions of the stem cankers, and condense into a dark thick-walled resistant form known as a sclerotium. As soon as moist or wet weather occurs in the spring, the exposed portions of these sclerotia produce from their surface the minute spore-bearing structures similar to those developed the previous season on the young lesions. The spores thus produced serve to infect the early spring growth and from the spots so formed the distribution of the disease takes place as before.

Control.

It has been found as a result of long experience that anthracnose can best be controlled by attacking the fungus in its hibernating stage. For this purpose any vines which bear the cankers formed during the previous growing season should be thoroughly swabbed with the following mixture:—

Iron sulphate	20 lb.
Sulphuric acid	8 lb.
Water	10 galls.

The iron sulphate is dissolved in 10 gallons of warm water in a wooden vessel. The sulphuric acid is then added by carefully pouring

in a thin stream, with constant stirring so as to avoid splashing and excessive heating. This solution will corrode metal vessels, and even wooden ones are best covered with tar or paraffin.

The solution should be applied just before the buds commence to move. Previous to this all badly diseased and unwanted wood will have been removed and burnt. The swabbing is conveniently done by means of a brush or small mop. Care must be taken that the whole vine and especially any old scars are thoroughly wetted.

Although the swabbing treatment will greatly reduce the amount of spring infection, it cannot be expected that this will be eliminated entirely. It is therefore advisable as a further precaution to spray the vines when the shoots are a few inches in length, and again a fortnight or three weeks later, with Bordeaux mixture of 6-4-40 strength. The applications of Bordeaux made subsequently for control of downy mildew will serve as a further check on anthracnose development.

Powdery Mildew of Apple.

The apple, pear, and quince may all at times be attacked by powdery mildew, but of these the apple is by far the most seriously affected. The fungus causing this mildew is not so dependent on wet weather for its development as are many other fungus parasites, and therefore damage may result from this disease even during a fairly dry season.

Symptoms.

All current season growth in the form of shoots, leaves, blossoms, and occasionally fruit is liable to attack. On the under surface of young leaves greyish-white powdery patches appear. These enlarge and may cover the whole leaf and then extend down the stalk to the twig. Affected leaves have their tissue hardened, with the result that subsequent growth is restricted and the foliage is stunted and deformed. The same white fungus growth will spread over the young twigs, and will also appear on some of the buds. In the latter case the floral parts become shrivelled and no fruit is formed. Sometimes young fruit are affected soon after they have set, with the result that a russeting is produced. After leaf-fall the affected twigs will be easily picked out by their white, silvery appearance. Many of the buds will be found to be dead, and the shoot itself may be killed back. (Plate 12, fig. 1.)

Effects.

Although the fruit often escapes injury, less obvious damage of a serious nature may result from mildew attack. The reduction in healthy foliage growth will mean a diminution in food supply, with consequent reduction in quantity and quality of the next crop. When the twigs are badly attacked the growth of next year's buds will be greatly interfered with, and these as well as part of the terminal itself may be completely destroyed. The setting of the fruit will be reduced by blossom infection in the spring.

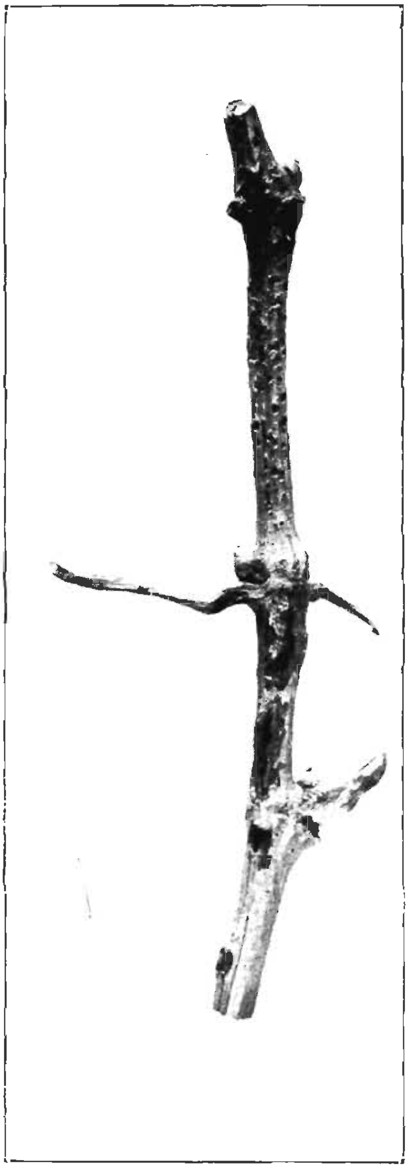


PLATE 12.

Fig. 1.—APPLE TWIG AFFECTED WITH POWDERY MILDEW. (Note the white fungal coat resulting dieback.)

Fig. 2.—GRAPE VINE EXHIBITING THE CANKER STAGE OF ANTHRACNOSE.

Cause.

The cause of apple powdery mildew is a fungus (*Podosphæra sp.*) which is allied to the organisms producing powdery mildew of the grape, cucumber, &c. Like these the apple fungus is ectoparasitic in its habit. In other words, the fine threads making up the fungal plant lie entirely on the surface of the host plant, nourishment being obtained by means of short suckers which penetrate the epidermal cells. It is these superficial mycelial threads which give rise to the white patches mentioned above. From the surface growth short upright threads are given off, and these, by a succession of transverse partitions, cut off numbers of delicate oval spores which, when distributed by wind and rain, serve to spread the disease throughout the orchard. (Plate 4A indicates this type of growth.)

Besides these summer spores or conidia, the fungus forms towards the latter part of the season another type of fruiting body known as a perithecium. These are dark-brown rounded bodies just visible to the naked eye, clusters together forming dark areas over the previously white patches. Within the perithecia are produced rounded sacs, each of which contains about eight ascospores. The ascospores serve to some extent to carry the fungus through the cold months. The chief method of over-wintering is, however, by means of fungal threads which penetrate among the scales of the leaf and flower buds and there hibernate until these organs commence to open in the spring. The fungus then grows along with the developing buds, and affects the young leaves and flowers as described above.

Control.

Since the fungus overwinters in affected twigs, all those exhibiting the white appearance denotive of the presence of mildew should be removed and burnt during the winter pruning.

The trees should be sprayed with lime sulphur 1 in 50—

(1) Just before the flowers open.

(2) When the last petals are falling. N.B.—For this and the next application the fungicide may be combined with the lead arsenate of the codling moth spray.

(3) About a fortnight after the last.

(4) Further applications will be necessary should powdery mildew again make its appearance.

Prune Rust.

Prune rust is a disease to which most of the cultivated varieties of stone fruits are subject, the peach and plum being most seriously affected. The disease is world-wide in distribution, and occurs in practically every region where its host plants are cultivated.

Symptoms.

The presence of prune rust is first denoted by the appearance on the upper surface of the leaf of somewhat angular spots of a greenish-yellow colour. These are few and scattered, or more numerous when they may become confluent and form large discoloured areas. The spots later darken to various shades of brown as the tissue dies and dries out. Frequently the leaf falls before this stage is reached. On the under surface of these spots the fruiting bodies of the fungus causing the disease appear as clusters of small brown powdery pustules (Plate 15, fig. 1). In the case of the peach the disease may also affect the young branches with the production of somewhat elongated brown pustules which rupture the bark. During a bad attack when rust appears early in the season, the fruit of both peach and apricot may become disfigured with brown slightly sunken areas as a result of infection by the rust fungus. Occasionally the stems and fruit of other varieties may be attacked.

Effects.

Rust usually attacks the lower leaves first, and these sooner or later turn somewhat yellow and fall. The disease then progresses more or less rapidly, according to weather conditions, up the branches, so that finally there may be left only a small tuft of leaves at their tips. Spotting may begin to appear about December or January, but during a fairly dry season it is not usually until the approach of autumn that the main defoliation occurs. It is on this account that some orchardists consider the effect of prune rust to be merely the leaf-fall natural to the approach of winter, and take no steps to combat a disease which, given the right climatic conditions, may be the cause of considerable loss.

It must be remembered that, since the peach, for example, produces its fruit on the previous season's wood, the premature loss of leaf in the one season, by reducing the development of this bearing wood, may affect the next season's crop. During a wet season defoliation may take place before the fruit has fully matured, with the result that the crop will be of poor quality or rendered worthless by sun-scald. Spotted peaches are unsightly in appearance, and, as the lesion extends some distance into the flesh, the fruit is rendered unfit for canning.

Cause.

Prune rust is caused by a fungus (*Puccinia prunispinosæ*) which, like other rust fungi, exhibit more than one fruiting stage. The more common spore form, which serves to spread the disease during the current season, is known as the uredospore. This is a somewhat angular brown spore produced from the tips of short erect fungal threads or conidiophores, which are closely aggregated together to form the pustules or sori mentioned above (Plate 5, fig. 5A). Towards the autumn there may appear, more especially on the plum, pustules of a dark-brown almost

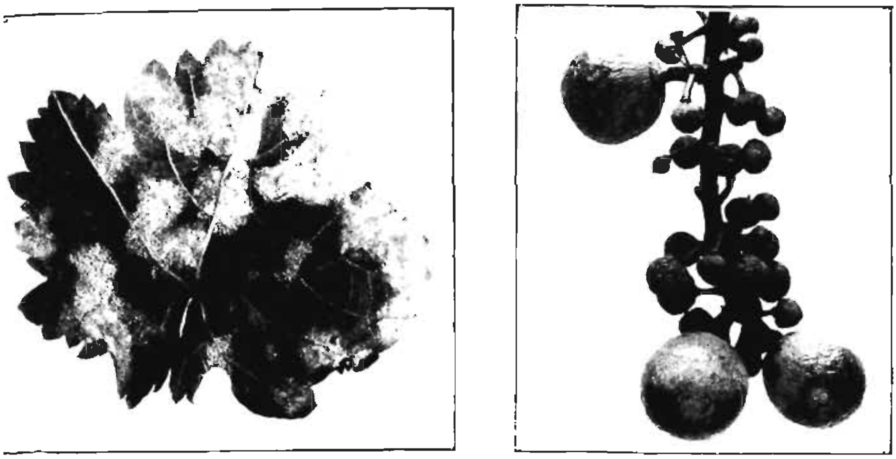


Fig. 1.—Downy Mildew of the Grape.

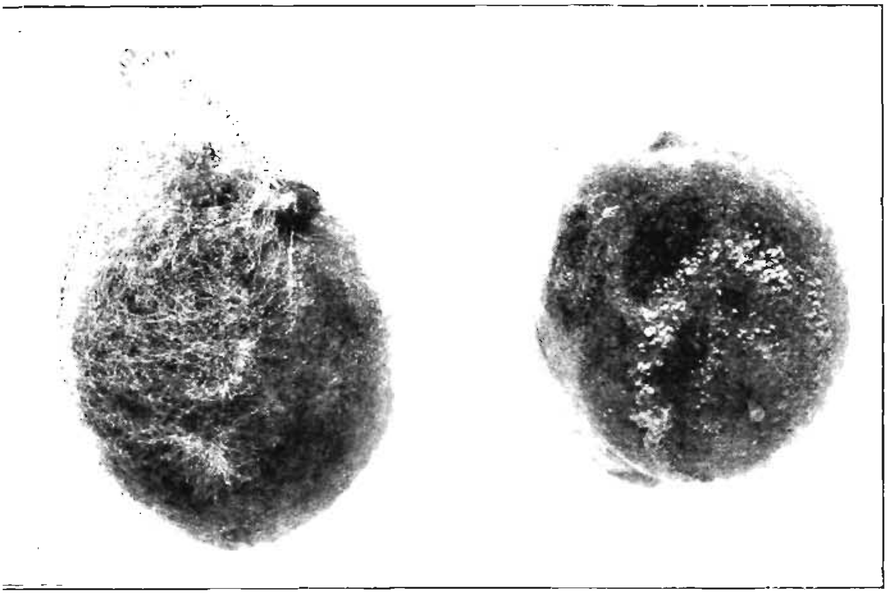


Fig. 2.—Two Peaches illustrating the difference between Black Mould Rot (left) and Brown Rot (right).

Plate 13.

black colour. In these sori are borne a somewhat thicker and more resistant two-celled spore, known as the teleutospore, which serves to carry the fungus over the winter and creates fresh infection in the following spring (Plate 5, fig. 5B). A warm wet season is most conducive to rust development.

CONTROL.

1. Prune out all infected twigs.

2. So far as is practicable, burn or plough under the fallen leaves, on which the fungus spores may be present in enormous numbers.

3. Spray as follows:—

(*a*) Bordeaux (6-4-40) or lime sulphur (1 in 10) just before the buds commence to swell.

(*b*) Bordeaux (4-4-40) or lime sulphur (1 in 50) as the leaves are expanding. Owing to the susceptibility of peach foliage to Bordeaux injury, peaches should receive the latter spray. Care must be taken that the fungicide reaches both sides of the leaves.

(*c*) Should rust make its appearance later in the season, the tree should receive a further spraying with lime sulphur (1 in 80).

Brown Rot of Stone Fruits.

Brown rot is probably the most serious disease affecting stone fruit in Queensland. Peaches, nectarines, and plums suffer most. Less frequently, apricots, cherries, and occasionally pome fruits are attacked.

SYMPTOMS.

Rotting of the fruit is usually the most striking symptom of brown rot, but there are other important manifestations which are often overlooked. The disease may commence in the early part of the season as a blossom blight. The floral organs turn brown and wither up but usually still remain attached. If the weather is moist, light-brown powdery spore masses, formed by the fungus causing the disease, may appear on the affected portions. The young twigs, and occasionally the leaves, may be attacked, either by direct infection by the fungus working down from diseased flowers or from spores developed on old mummied fruits. The fungus may pass through the smaller twigs into an older branch, and there produce a large irregular wound or canker.

The fruit may be attacked at any period of its growth, though it is more commonly affected when approaching maturity or during storage. The first symptoms appear as a small brown spot on the skin of the fruit, often associated with a slight injury. If the atmosphere is moist

this spot will enlarge rapidly and may involve the whole fruit in twenty-four to forty-eight hours. When the brown area is an inch to an inch and a-half in diameter the fungus usually commences to form its fruiting stage. This appears on the surface of the affected region as light greyish brown powdery tufts often arising in more or less concentric rings (Plate 14, fig. 2). The fruit rot is at first soft, but later the decomposition ceases and the flesh dries out with the production of a firm, dry, shrunken object commonly known as a "mummy" (Plate 14, fig. 1). In pome fruits there is a tendency for the rotting fruit to turn black rather than brown.

Cause.

Brown rot is due to the attack of a fungus (*Sclerotinia fructicola*) belonging to the Ascomycetes or sac fungi, and in common with many other members of the group exhibits two distinct methods of reproduction. The common form met with in Queensland is known as the monilia stage. Clusters of thread-like hyphæ push through the surface of the fruit, branch once or twice, and then divide up into bead-like chains of cells which are cut off as spores when mature. It is masses of these structures which form the greyish tufts described above.

The second and perfect stage of the fungus is found (apparently rarely in Queensland) in connection with old mummies which have lain on the ground for a year or more. There is developed from the fungus mycelium within the dried fruit small-stalked saucer-shaped structures. The upper surface of these receptacles consists of narrow, cylindric, sac-like cells, each of which contains eight smaller ascospores. In countries where this stage is produced in quantity the ascospores serve to start the spring infection of the blossoms.

In Australia the fungus overwinters as dormant mycelium, either in cankers and invaded twigs or in the mummified fruit lying on the ground or still attached to the tree. Within the tissue of these organs the massed fungal threads live through the winter in all security. At the approach of warm, moist, spring weather the mycelium again becomes active and bursts through the surface layers to form the greyish-brown tufts of spores by means of which the spring infection commences.

Control.

1. Prune out all twigs whose appearance might suggest infection with brown rot, as otherwise they may be the means of carrying over the disease to the next year.

Carefully remove all mummied fruit and collect those already fallen and destroy by fire or burying.

2. Spray with a fungicide. Owing to the ease with which the peach and some other stone fruits are injured by the common spray mixtures, it is difficult to obtain a spray which will be sufficiently potent

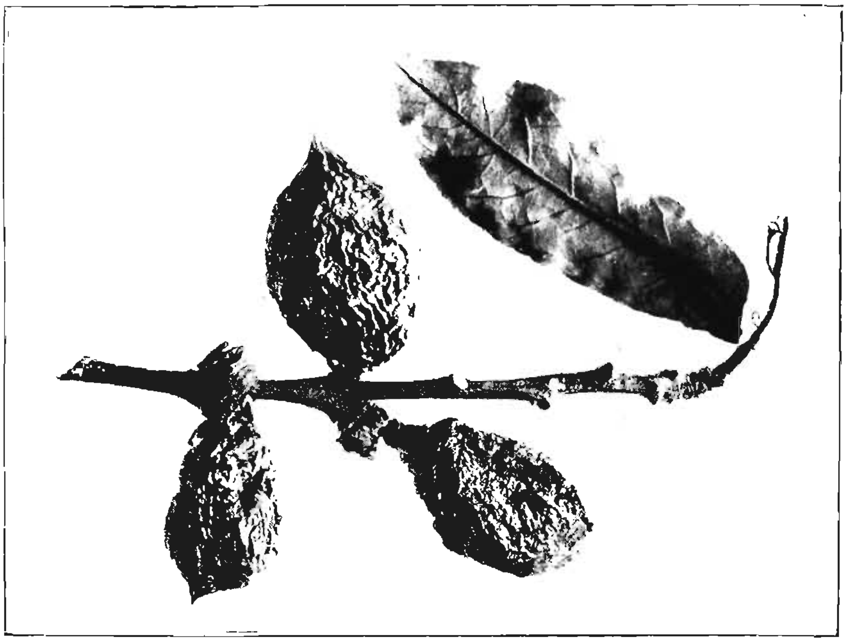


Fig. 1.—Nectarine fruit mummified as a result of Brown Rot attack.

Fig. 2.—Brown Rot of Nectarine. In the fruit on the right infection has originated in a bruise.

Plate 14

against brown rot and yet not injure the plant. C. C. Brittlebank, in Victoria, has lately tried out the following schedule on peaches with considerable success:—

(1) Just before the buds begin to swell, spray with lime sulphur 1 in 9 of Baumé 32 deg.
(2) As buds show pink: Lime sulphur 1 in 35.
(3) As the fruit begins to colour: Lime sulphur 1 in 80.
(4) One month to three weeks before picking: Lime sulphur 1 in 100.

3. Examination of affected fruit at the market would suggest that an injury of some form is often responsible for brown rot infection. Care should therefore be exercised during picking and packing operations to see that injuries in the form of bruises, scratches, &c., are so far as possible avoided. Affected fruit should not be touched while handling sound ones, and all rot material should be kept out of the packing shed. When possible avoid picking and packing when the fruit is wet.

Black Mould Rot of Stone Fruits.

Black mould rot is a storage trouble sometimes confused with the true brown rot. It has been found affecting more especially peaches and plums, and in connection with these varieties has in some seasons been responsible for even more loss than brown rot.

Symptoms and Cause.

This rot commences as a small brown spot on the surface of the fruit, and in its early stages is indistinguishable from brown rot. Later, instead of the small compact powdery spore masses characteristic of this latter disease, there arise long delicate greyish-white threads of mould growth, which radiate out from the affected region (Plate 13, fig. 2). This mould growth belongs to the fungus (*Rhizopus nigricans*) causing the disease. A single mould "plant" possesses a number of root-like branched threads which ramify amongst the tissue of the fruit, which they destroy and so cause the brown rot. From the point of origin of these root-like processes there is given off a number of long slender aerial threads which are the spore-bearing structures or sporangiophores. These swell at the apex to form a globular sac or sporangium. Within the sporangium the protoplasm divides up into a great number of minute rounded spores which are finally liberated by rupture of the sporangium wall (Plate 5, fig. 1). The sporangia are at first white but as the spores mature they turn dark grey to almost black, and, being just visible to the naked eye, give a grey speckled appearance to the mould growth covering the fruit. Beside the spore-bearing hyphæ there is given off from each fungal "plant" one or more long slender threads or stolons, which grow out over the surface of the fruit until it in its turn becomes attached at some point and develops root-like processes which may penetrate the as yet uninjured skin and so commence a new point of rot.

The original infection of the fruit by means of spores appears to take place very largely if not entirely per medium of injuries to the skin, often very slight, in the form of scratches, bruises, &c. Once a point of infection has been created the mould quickly spreads by means of the stolons over the fruit and from there to the as yet sound ones adjoining. Under suitable conditions a day or two may suffice for the formation of large "nests" of rotten fruit bound together by the abundant grey mould growth commonly called "whiskers." Half a case or more may be involved in one of these nests. It is the rapid spread through a case which enables this mould when present to be responsible for greater loss on the market than brown rot.

Control.

Since wounds appear necessary for the introduction of black mould, and the disease is one of stored fruit, control measures will have to be along similar lines to those found useful in connection with blue mould of citrus.

1. Avoid picking and packing during showery weather and when the fruit is wet. A marked increase of this rot has been noticed during periods of wet weather.

2. Take special care during picking and packing operations to see that the fruit receives no unnecessary injury. Finger-nail scratches and case bruises may be a source of trouble. All fruit showing injury or blemish should be rejected.

3. Cleanliness in the orchard and packing house is essential. All rotting fruit should be collected at frequent intervals and destroyed by fire or burying.

4. If the quality of the fruit is such as to make wrapping a justifiable outlay, this procedure would greatly reduce the loss by localising the attack to the originally infected fruit.

Peach-leaf Curl.

Leaf curl is a disease affecting chiefly the peach and nectarine, other varieties of stone fruits being rarely attacked. Like rust, this disease is widely distributed throughout the peach-growing centres of the world. Fortunately it is one of the plant maladies most easily controlled.

Symptoms.

Leaves, young shoots, and fruit may be attacked, but the most common and characteristic symptoms appear on the first-mentioned. Affected leaves as they issue from the bud appear of a somewhat yellow or pinkish colour, and on expanding become all or in part curled and puckered (Plate 15, fig. 2). The deformed portions are considerably thicker than the normal leaf, and retain their unnatural colouration for some time. Later this is masked by the development of a grey bloom due to the formation of a layer of the fruiting bodies of the fungus causing the disease over the upper surface.

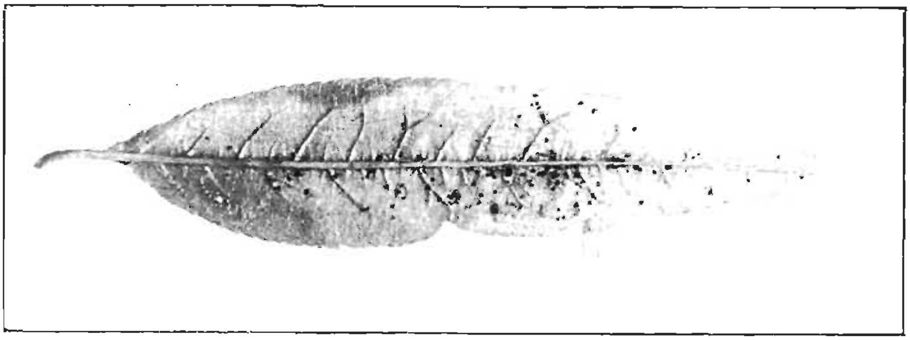


Fig. 1.—Peach leaf showing the sori formed by the Rust fungus (*Puccinia prunispinosæ*).

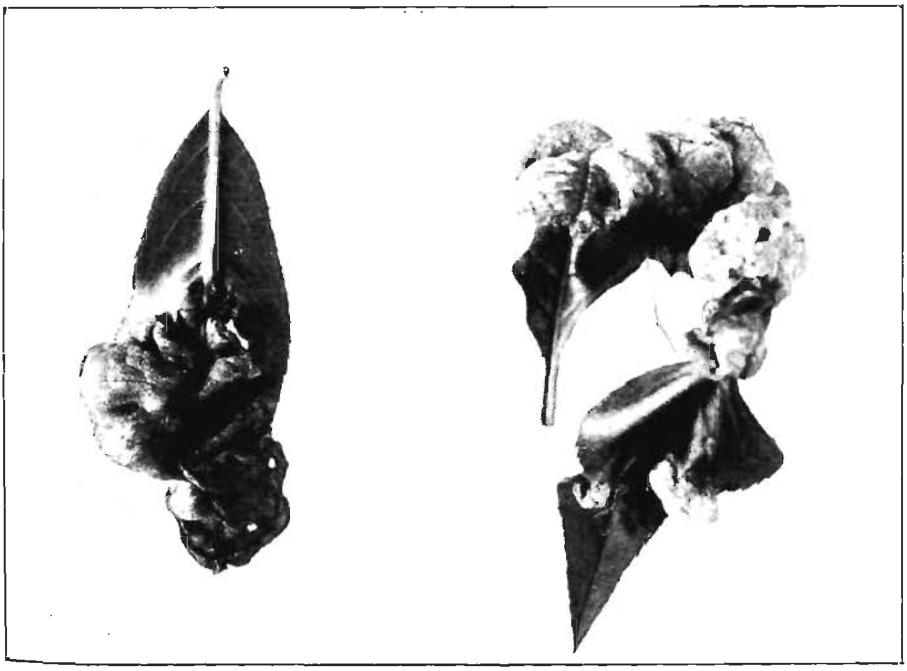


Fig. 2.—Peach leaves exhibiting the malformation characteristic of Leaf Curl.

PLATE 15.

Finally the leaf turns brown and falls off. If the original infection was heavy the defoliation may be extensive. A new set of leaves is usually formed from dormant buds, but these may be developed too late to mature the fruit and next season's bearing wood. Repeated defoliation lowers the vitality of the tree and may eventually lead to death.

Cause.

Leaf curl is induced by a fungus parasite (*Taphrina deformans*), which is one of the more simple type of sac fungi or Ascomycetes. The presence of the mycelial threads of this fungus within the tissue of the leaf stimulates the latter to abnormal growth both in size and number of its constituent cells. This enlargement takes place mostly on the *upper side of the leaf*, with the result that the leaf becomes puckered and curled as described above. Later the fungus grows out between the epidermal cells and forms on the surface a layer of close, erect, oblong cells known as asci. Each of these contains eight rounded spores known from their method of formation as ascospores (Plate 5, fig. 2). They are liberated by rupture of the enclosing sac.

Some of the ascospores fall into sheltered situations where they are able to pass the winter, to germinate the following spring and infect the developing buds. Cool, moist weather when the buds are swelling provides conditions very suitable to leaf curl attack.

Control.

This disease can be effectually checked by the application of a fungicide before the buds begin to swell in the spring. For this purpose Bordeaux mixture (6-4-40) or lime sulphur 1 in 10 may be used.

CHAPTER VIII.

PESTS AND DISEASES OF CITRUS.

The citrus orchards of Queensland frequently suffer from severe insect infestations which are responsible for more or less serious losses to the orchardists. Some of the pests in question are practically cosmopolitan introduced insects, whereas others are native species which have turned their attention from indigenous wild host plants to cultivated orchard trees.

Among the more important citrus insects that are worthy of consideration in these notes are the bronzy orange bug, the "Maori" mite, the orange-piercing moths, the red scale, the citrus root-bark channeller, the Queensland fruit fly, the pink wax scale, and plant lice. Quite a number of other insects and allied pests of citrus exist in this State. but for present purposes attention will be confined to those just mentioned.

The diseases dealt with in this chapter are black spot, melanose, blue mould, scab, exanthema, dieback, collar rot, and sooty mould.

The Bronzy Orange Bug.

The insect known as the bronzy orange bug was recorded as far back as 1889 as a pest on citrus in the Toowoomba district. It has since been found injuring citrus in many different orcharding centres in Queensland, and it has also been recorded from the neighbouring State of New South Wales. It has in recent years been particularly abundant on the Blackall Range in this State.

The bronzy orange bug belongs to the Pentatomidæ in the order Hemiptera, and is known to science as *Oncoscelis sulciventris* Stål.

Feeding Habits and Nature of Injury.

As is the case with all the members of the order to which this pest belongs, feeding takes place by means of piercing mouth-parts. The epidermis or skin of the host plant is pierced, and through the rupture thus made the bug extracts the plant sap.

Field observations suggest that the bugs confine their attention to young and tender growth. They are found feeding on stems and leaves of young twigs and on flower and fruit pedicels, and they may also attack the young fruit.

The effect produced by the feeding of the bugs is typical of the class to which they belong. The attacked twigs (Plate 16) wilt and shrivel up, and the buds and young attacked fruit drop off. When the bugs are present in the numbers that have been recorded in certain orchards in the Blackall Range district, it is not difficult to appreciate the serious situation that may be created by the activities of this pest.

Plate 16.—Orange Twig Attacked by the Bronzy Orange Bug (*Oncoscelis sulciventris* Stål).

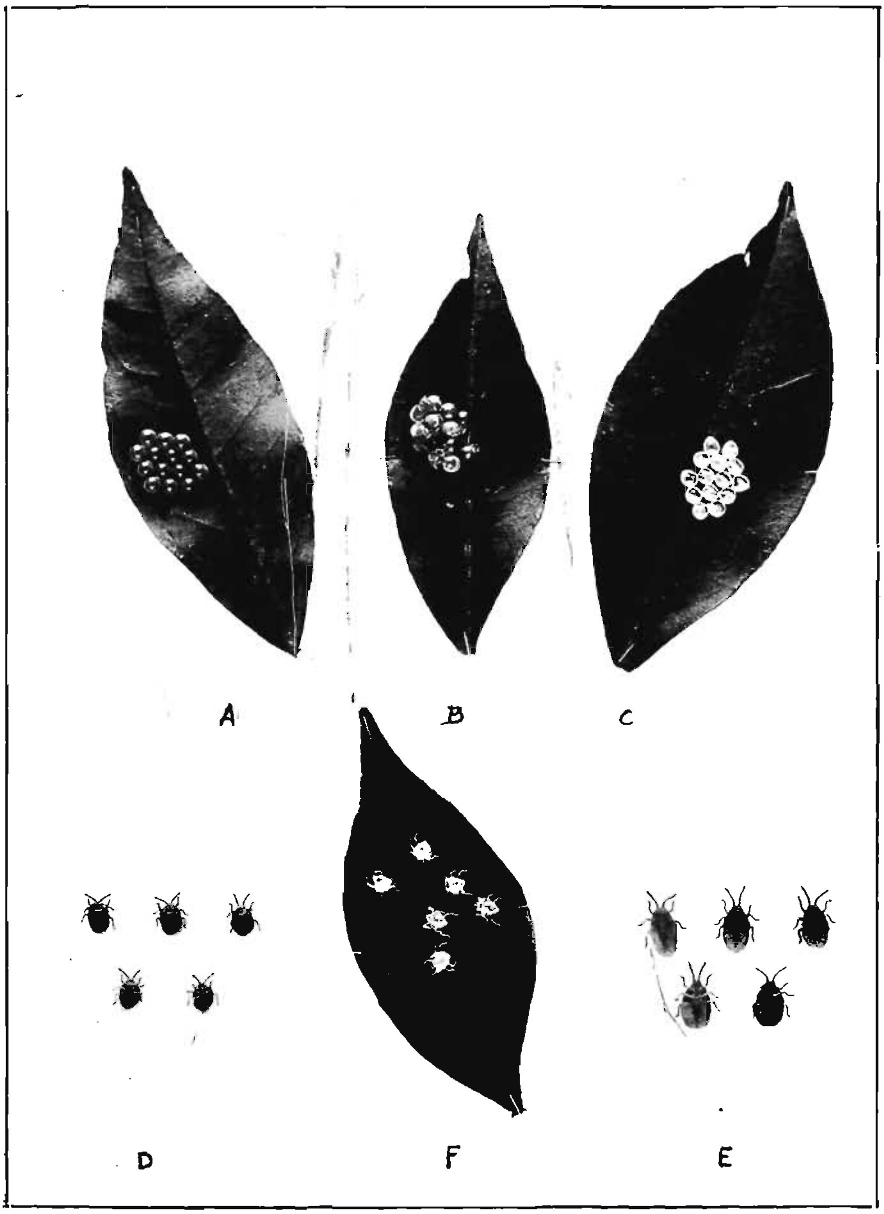


Plate 17.—The Bronzy Orange Bug (*Oncoscelis sulciventris* Stål).

Fig. A.—Egg cluster.
Fig. B.—Eggs hatching.
Fig. C.—Empty eggshells.
Fig. D.—Young nymphs.
Fig. E.—Somewhat older nymphs.
Fig. F.—Cast nymphal skins.

Oranges, mandarins, and lemons are all attacked by this serious pest. It is believed to be a native of Australia, and the suggestion has been made that it feeds on native species of Rutaceae. Its association with native plants is, however, worthy of further consideration.

Life Cycle Stages and Life History.

As this insect belongs to the Hemiptera it possesses what is known as an incomplete metamorphosis. In insects of this class the newly hatched wingless individual or nymph bears some slight degree of resemblance to the mature winged insect, into which it will gradually transform during a period of growth that is accompanied by a series of moults. The life cycle of this species may thus be divided into three distinct stages; firstly there is the egg, followed by the wingless nymph, which after a series of moults produces the winged adult.

The Eggs.

The green, shiny, spherical-shaped eggs (Plate 17, fig. A) are laid in rows in small masses, the number in each egg cluster being usually extraordinarily constant at fourteen. The eggs are laid on the foliage in summer anywhere on the tree, the under sides of the leaves being generally chosen for oviposition. The eggs pass through the usual incubation period, which is recorded by Tryon as being eight or nine days.

The Nymphs.

At the end of the incubation period the eggs hatch and the very small nymphs emerge. These are green in colour and are oval and somewhat convex in shape. They remain together without dispersing over the foliage, and it is believed that they either do not feed at all or, if they do, they partake but sparingly of food. A further noteworthy characteristic of these first-stage nymphs is the fact that they are very easily disturbed and will drop to the ground on the slightest provocation. The duration of this first stage is somewhat uncertain, but it is evidently brief and the nymphs then moult into the second stage.

The second-stage nymph resembles the first stage in its green colour, but it is very much flatter in shape and it clings extremely closely to the under surface of the leaf on which it is resting. It is by no means readily shaken from the host tree, and it further differs from the first stage in that it disperses over the foliage instead of the individuals of each egg cluster remaining close together. It is in this stage that the insect passes the winter in a state of inactivity. The nymph in this stage resembles the leaf so wonderfully in colour, and is so closely adherent thereto, that its presence even in very considerable numbers cannot be detected without careful examination. The second-stage nymphs, which have passed the winter in a state of inactivity, commence to crawl about in search of food late in August or early in September. By that time the citrus should be showing some tender young shoots, and it is on these shoots that the second-stage nymphs now commence feeding.

The third-stage nymph has its body decidedly flattened like the second-stage nymph. Observations by A. A. Girault in the Blackall Range district, in the spring of 1923, showed that by the end of September the great majority of the bugs that had hibernated as second-stage nymphs had moulted into the third stage.

The same records showed that by the end of October approximately half the bugs were in the fourth nymphal stage, while the remaining half were in the fifth. A few were still in the second and third stages, while one adult was found.

Nymphs in the fourth and fifth stages show distinct signs of the development of the wing-buds, and their colour scheme possesses certain features distinguishing these two stages from the three earlier ones.

The various nymphal stages are illustrated in Plates 17 and 18.

The Adult.

The adult bug (Plate 18) is just about an inch in length, and its colour scheme is somewhat appropriately described by its popular name of bronzy orange bug. There is little to distinguish the two sexes, although the male is generally considered to be smaller than the female. The under side of the abdomen in the female also possesses a median channel which does not occur in the male.

In the 1923 observations in the Blackall Range the first adults were found at the end of October, and from then on until midsummer there was a steadily increasing percentage of adults. The adults in both sexes are voracious feeders.

Summary of Life History and Habits.

The green spherical-shaped eggs are laid in clusters of fourteen on the under sides of leaves in summer, After an incubation period of some eight or nine days the eggs hatch, yielding small green nymphs which remain clustered together and apparently make little or no attempt at feeding. These then moult into the second-stage nymphs, which scatter over the host plant and pass the winter in a state of inactivity. In spring these second-stage nymphs commence to feed on the tender young shoots and then moult successively into the third, fourth, and fifth nymphal stages and finally transform to the winged adults, which mate and lay their eggs in summer, thus recommencing the life cycle. There is thus only one generation each year.

Control Measures.

Much relief from this pest has been obtained by the adoption of the system of banging, accompanied by the cincturing or banding of the trees after banging. A padded mallet is used in order to sharply jar the various branches of infested trees, care being taken to ensure that the branches are not injured in the course of the operation. This work is best performed in spring-time, when third and fourth stage nymphs predominate. The nymphs in these stages will fall to the ground rather readily, and when that has been accomplished steps must be taken to

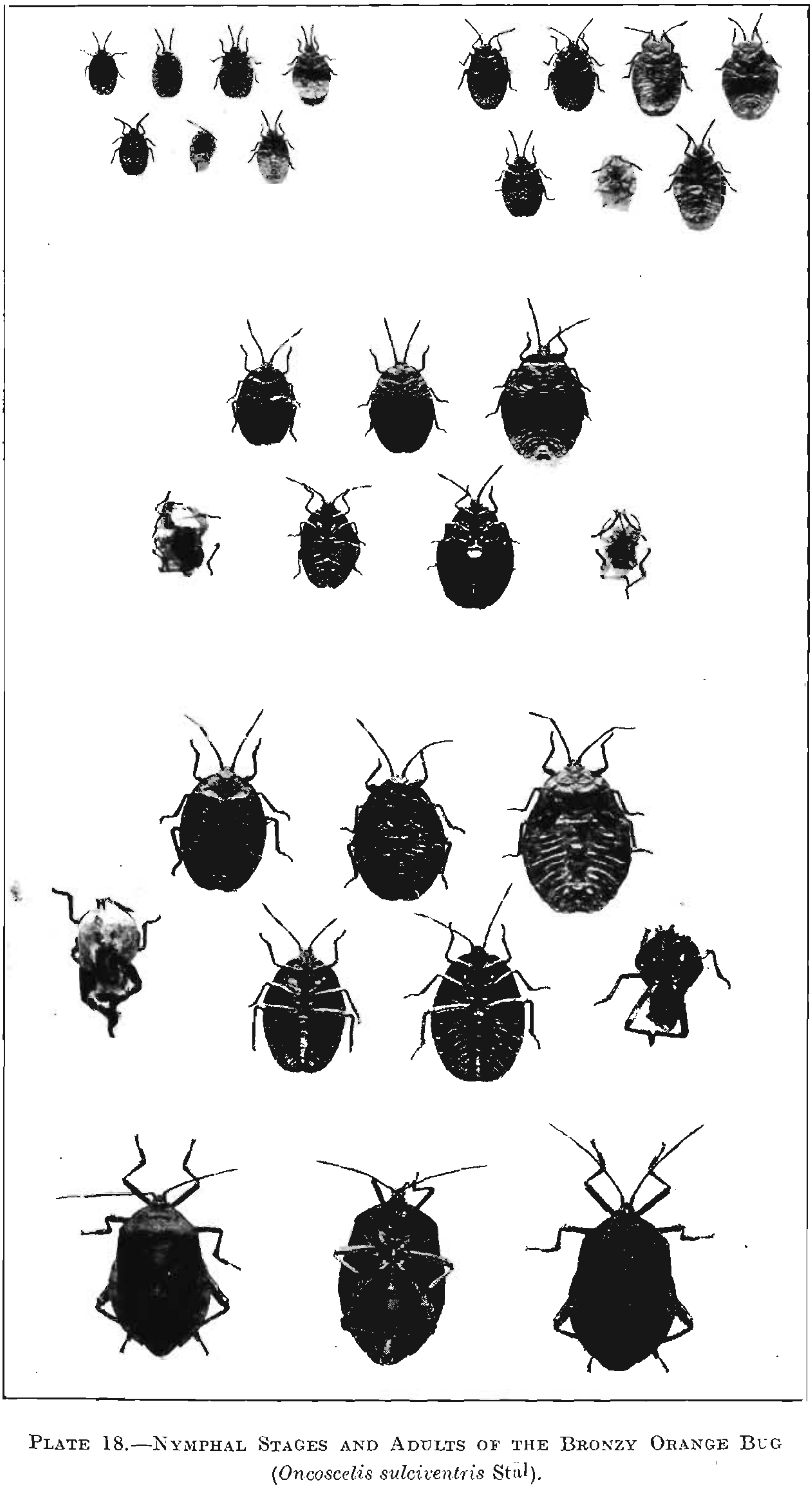


PLATE 18.—NYMPHAL STAGES AND ADULTS OF THE BRONZY ORANGE BUG (*Oncoscelis sulciventris* Stål).

prevent these wingless nymphs returning to the trees. This object may be achieved by building an earthen cone round the base of each tree, say 9 or 10 inches high, and then partially cutting the cone away so as to leave a steep face about 5 or 6 inches high up which the bugs cannot readily crawl. The return of the bugs may also be prevented by banding the tree with bands carrying sticky substances that will form a barrier which the bugs cannot cross. Tanglefoot has been used for that purpose. Some orchardists destroy the fallen nymphs by scorching them up with a blow-lamp, and this additional precaution ensures that there will be no possibility of return by some of the nymphs succeeding in crossing the bands or earthen cones. Bands are preferable to earthen cones.

The 1923 observations already referred to included spraying experiments, and these demonstrated the fact that, under the conditions then prevailing, spraying was not effective for the control of this insect.

Readers who desire further details with respect to this pest should consult the reports published by Tryon and Girault on the results of their investigations in 1923.

The Citrus Rust Mite or " Maori " Mite.

Quite frequently oranges and lemons are found to be infested by a small mite known variously as the citrus rust mite, "Maori" mite, fruit mite, orange rust mite, or silver mite (*Phyllocoptes oleivorus* Ashm.). The oranges attacked by these mites acquire a characteristic dark-brownish tinge and are generally referred to in Queensland as "Maori" oranges.

No details are available with respect to the life history of this mite in Queensland, but in California some considerable information has been published thereon. Briefly it is to the effect that the extremely small circular and somewhat yellowish eggs are laid on the fruit or foliage either singly or in small clusters. These eggs hatch out after an incubation period of about a week in the warmer weather, and by a succession of moults the mites attain full size in some two or three weeks. Their breeding season lasts from spring till late in autumn, and thus a large number of broods are produced every year.

The individuals of this species are extremely small, light-yellowish, four-legged mites; they are indeed so small that they can be observed only by means of a lens, being invisible to the naked eye. Their presence, therefore, can most easily be detected by the effects produced by their feeding. Both the immature forms and the adults of the citrus rust mite pierce the oil-cells and feed on the oil. The bark, the foliage, and the rind of the fruit are all attacked in the search for food, and as the mites sometimes occur in enormous numbers they can cause appreciable damage. As a result of their presence on the fruit, this is stained the brown or dark brown that is characteristic of the "Maori" orange. The appearance of the fruit that has been discoloured by this infestation is undoubtedly by no means attractive, but the quality of the fruit is not necessarily impaired.

With regard to control, this may be effected by spraying with a weak solution of lime sulphur or by dusting with sulphur. Citrus rust mite, however, is generally quite a minor pest of citrus.

The Orange-piercing Moth.

The orange-piercing moth (*Othreis fullonica* Linn.) and two other allied moths of similar feeding habits—namely, *Mœnas salaminia* Fab. and *Argadesa materna* Linn. (Plate 21)—frequently appear in very large numbers in citrus districts during the autumn months. They are large handsome moths possessing the exceptional power of being able to pierce the rind of fruit and to extract the juices through the punctures thus made. The sucking or sipping of juices is, of course, quite the normal procedure in moths, the abnormality in this case being the power to pierce the rind of the fruit in order to obtain fruit-juice. An examination of the proboscis of one of these moths readily discloses the fact that it is highly specialised to permit of this habit, so unusual in moths. A discussion of the details of the modification of the proboscis, however, is quite unnecessary in these notes, although it is of great scientific interest.

The moths themselves are large, exceptionally handsome species that are well illustrated in the accompanying photographs (Plates 19 and 21). The larva of *Othreis fullonica* is quite in keeping with the moths so far as appearance is concerned, for it is a particularly handsome caterpillar (Plate 20).

The larvæ feed on various native plants, and are themselves of no economic importance except by virtue of the fact that they develop into the moths that attack fruits of certain cultivated plants. The fruit-piercing moths have been recorded as attacking citrus, bananas, and mangoes. During the autumn of 1927 they were particularly destructive throughout coastal Queensland.

For the control of this pest, perhaps the best that can be done is to capture the moths at a lure. For this purpose over-ripe bananas, of which they are particularly fond, may be used, and these should be placed in suitable spots, visited daily after dark, and the moths feeding on them captured and destroyed. Small pieces of water-melon have also been strongly recommended as a lure; these have to be similarly visited and the moths destroyed. To obtain maximum results from this operation it should be commenced very early in the season.

If it is practicable to do so, the native plants on which the caterpillars of these moths are feeding should be destroyed.

The Red Scale.

The red scale (*Chrysomphalus aurantii* Maskell) is without doubt one of the most serious pests of citrus in Queensland, and indeed it may even be regarded as worthy of classification among the world's most

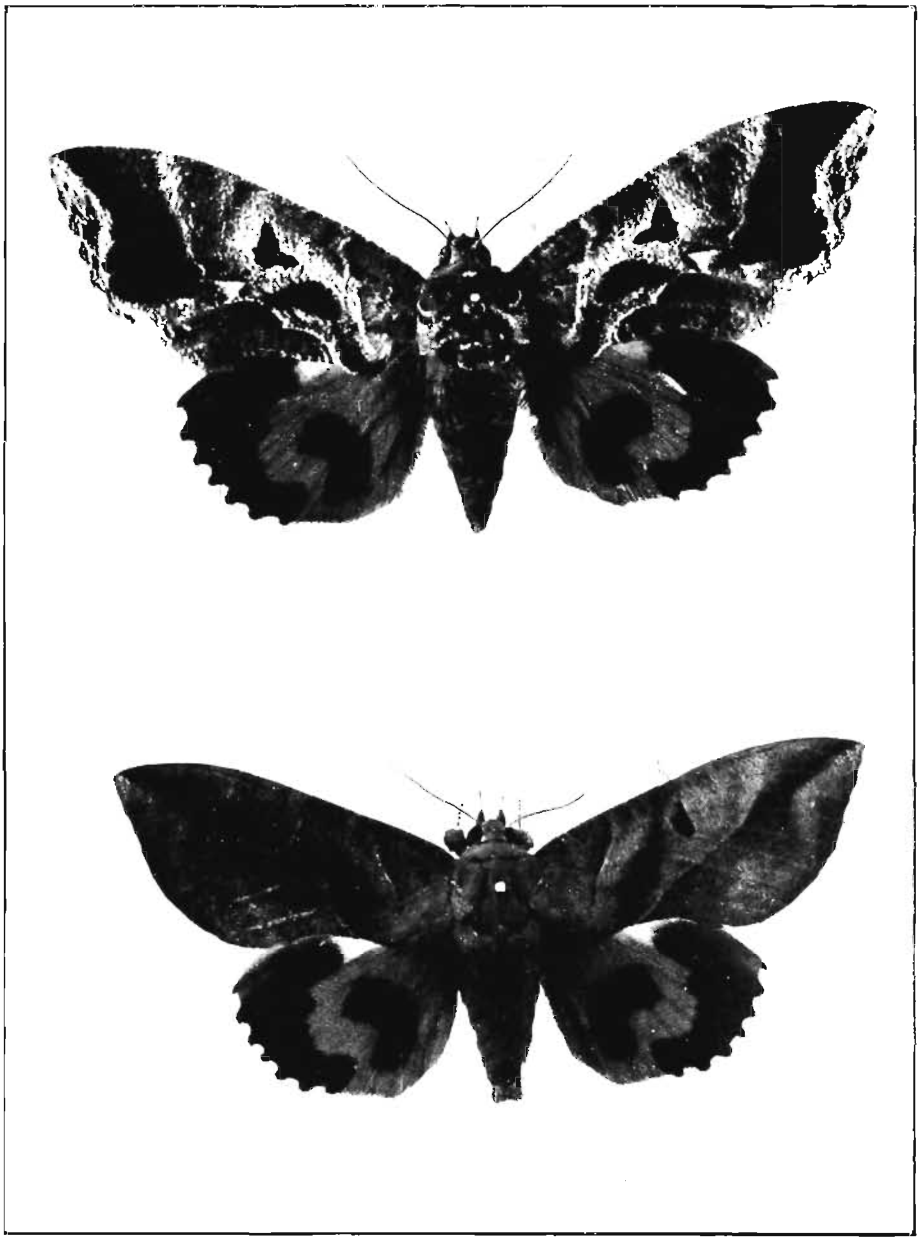


Plate 19.—The Orange-piercing Moth (*Othreis fullonica* Linn.).
Male and Female Moths.

destructive citrus insects. It is now practically world-wide in its distribution, at least so far as the tropical and semi-tropical regions are concerned. As is not unusual in the case of insects that have become widely distributed throughout the world, there is some considerable uncertainty with respect to its native home. It is not regarded, however, as being indigenous to Australia, and it would seem that evidence exists in favour of the belief that it originally came from China or elsewhere in the Far East.

This scale does not confine its attention to citrus, but it is as a pest of citrus that it has acquired its unenviable reputation. Other plants attacked include apple, pear, quince, plum, fig, olive, coconut, and rose. As already indicated, however, it is not a pest of importance except on citrus.

The effect of red scale, if allowed to multiply without the check administered by the application of control measures, is usually very serious. It attacks all parts of the tree, i.e., the foliage, the fruit, and the branches, and when a tree is severely infested many of the leaves will be shed and many branches killed. A tree that is so affected is naturally of little profit to an orchardist, and what fruit is produced is unattractive and frequently unsaleable. This scale insect does not excrete honeydew, and hence its presence is not accompanied by the occurrence of fumagine or sooty mould. Fumagine is the term applied to a fungus that grows on the honeydew or sweet substance excreted by certain species of scale insects. Fumagine does not attack the plant tissue, and apart from the unsightly appearance produced it is of relatively little consequence.

The red scale is viviparous—i.e., no eggs are laid and the young appear as very small larvæ. These are sulphur yellow in colour and possess three pairs of legs, thus enabling them to move about in search of a suitable spot at which to settle down. When that has been obtained they commence to form the scale covering which gives these insects their popular name. Under these scales the insects develop to maturity, the female adults becoming rather degenerate legless and wingless insects. The adult males are totally different in appearance, and possess a pair of wings and three pairs of legs by means of which they are able to travel from tree to tree in search of mates. Although the power of flight of the winged male is slight it is frequently transported long distances by wind. The scale of the full-grown female is about $\frac{1}{12}$ inch or slightly more in diameter and is distinctly circular in shape. It is transparent, and this fact allows the red colour of the female insect to be seen quite clearly, hence the popular name of the red scale. The scale covering the immature male insect is smaller than the scale of the female, and is elongate in shape rather than circular.

With respect to control, fumigation with hydrocyanic acid gas can be strongly recommended. Fumigation is discussed in some detail in

the chapter dealing with insecticides. Spraying is also adopted for the control of this pest, resin wash and miscible oils being used for that purpose.

The Citrus Root-bark Channeller.

Like the notorious banana weevil borer, this citrus pest belongs to the Curculionidæ. It was technically described in 1920 as *Decilaus citriperda* H.T., but it is more commonly known among orchardists as the citrus root-bark channeller. It appears to have first become the subject of attention as far back as 1908, and since that date it has frequently figured in routine inquiries regarding the control of injurious insects. Reference to its attacks on citrus appears to come mainly from the Blackall Range, although recently a number of inquiries have been received from elsewhere on the North Coast.

Nature of Injury.

The examination of an attacked tree readily provides evidence of the nature of the injury if the base of the stem and the roots in proximity thereto are inspected. It will then be seen that a number of channels have been excavated at the base of the stem and on the surface of the roots, and that on the latter the channels may extend outwards for several feet from the base of the stem. In the case of an old attack the channel is exposed by the decay of the thin layer of bark that originally covered it, but in a more recent infestation the outer layer of the bark is still present, and on that account the extent of injury may be somewhat masked. It may be further observed that in many of the older attacks the infested trees have attempted to heal the wounds, and these efforts have in some instances been attended with a certain measure of success.

The inspection of infested roots has so far shown that, although frequently quite a considerable number of individual channels may exist in the one root, they do not run into each other and ringbarking is not associated with infestation. This is a somewhat fortunate feature in the feeding habits of the citrus root-bark channeller, and it rather mitigates the seriousness of its presence in an orchard. Were a ring-barking effect typical of its presence it would be a more serious pest than it is. Nevertheless the infestation on a root may frequently be so very considerable as to practically completely destroy it, and obviously when a number of roots of one tree are so attacked the growth of the tree and the production of fruit must be very seriously retarded.

Trees Attacked.

The roots of both orange and mandarin trees are attacked, and it also seems probable that this pest feeds on the roots of some native species of plant or plants. This supposition has not yet been confirmed, but nevertheless the citrus root-bark channeller is believed to be a native species of weevil that has transferred its attention from a native host plant to cultivated citrus trees.

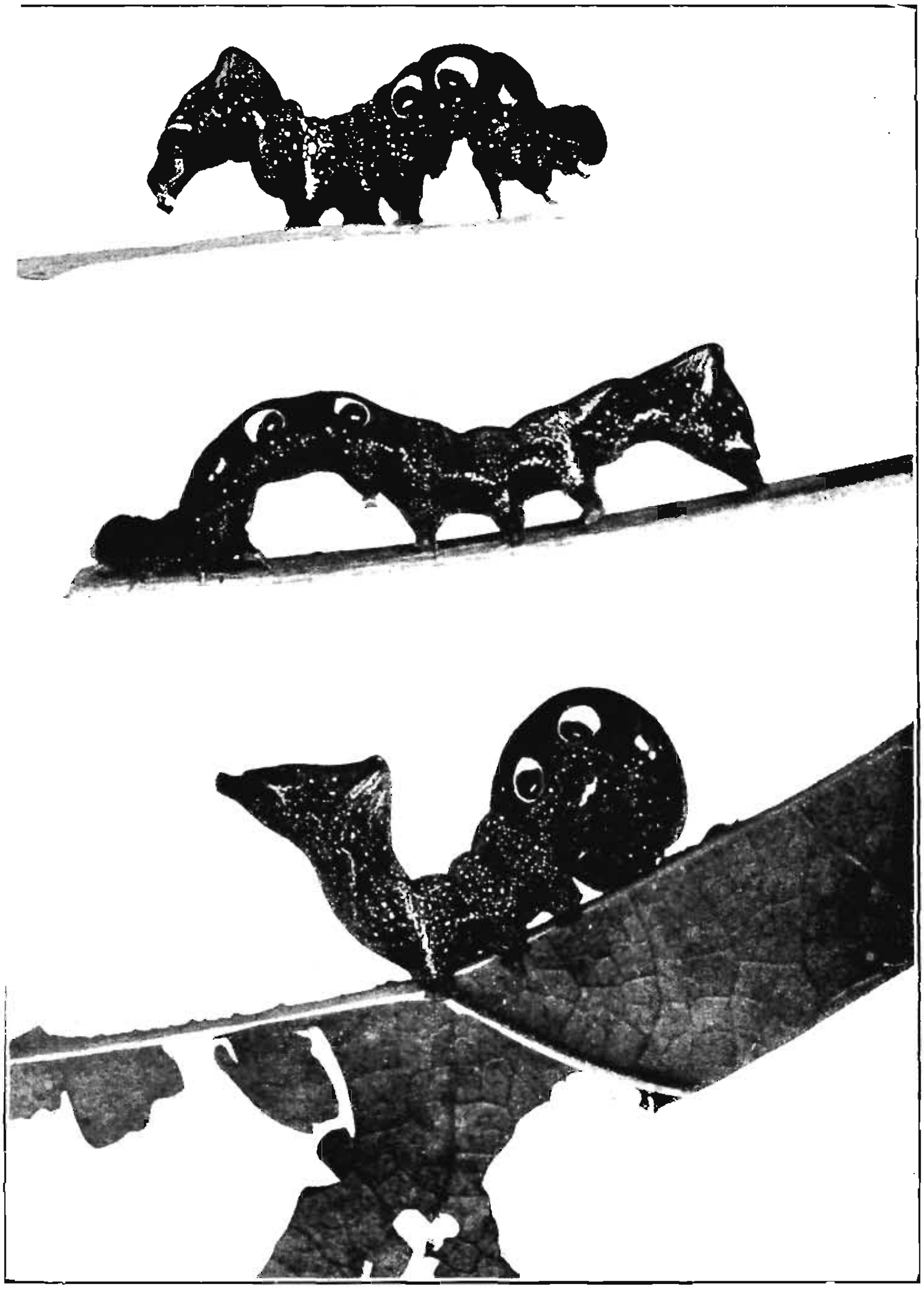


PLATE 20.—LARVÆ OF THE ORANGE-PIERCING MOTH (*Othreis fullonica* Linn.).

The information accumulated to date rather tends to support the belief that this weevil favours the older trees, and that young citrus, if attacked at all, is but slightly infested. It has also been thought that, in the older trees, lack of vigour may be a predisposing factor to severe infestation; this lack of vigour may be the result of growth under unfavourable circumstances such as unsuitable soil conditions, lack of attention, or unfavourable seasons. The whole question of the incidence of infestation appears, however, to warrant further attention.

LIFE CYCLE STAGES.

Beetles possess four distinct stages in their life cycles, each of these stages having very definite functions to perform; they are the egg, larva, pupa, and adult or beetle. The second stage, i.e. the larva or grub, is the one in which the damage is done to the roots of citrus by the particular species at present under discussion. It is creamy white in colour, legless, and otherwise rather featureless, and measures about $\frac{1}{3}$ inch in length. The pupa is characteristic of its class, and in it the legs, wings, and head of the future beetle can be clearly seen. The beetle itself is a typical black weevil measuring roughly about $\frac{1}{4}$ inch in length.

CONTROL MEASURES.

In attempting to control this pest the orchardist may adopt either or both of two courses. He may endeavour to stimulate the growth of the infested trees, thus enabling them to better resist and repel the infestation, or he may attempt to destroy or drive off the weevils responsible for the damage.

If this pest, as there is good reason to believe, is more commonly met with in the older trees that are in a state of decline as a result of adverse conditions other than root-bark channeller infestation, then the adoption of the first-mentioned alternative seems worthy of serious consideration. Anything that would tend to eliminate these unfavourable conditions would thus check the tree's decline in vigour, and would therefore help to alleviate the insect infestation. If the trees are suffering from unfavourable soil conditions, efforts should if practicable be made to counteract these adverse soil conditions; if cultural practices have been faulty these should be rectified; and if scale infestation is heavy that should be remedied by fumigation or by suitable spraying. Even if the old trees that are attacked are otherwise perfectly healthy, their growth should be stimulated to enable them to withstand the attack.

The alternative to these measures is to attempt to destroy the insects by the adoption of some form of soil fumigation. It must, however, be pointed out that so far no satisfactory system of soil fumigation has yet been demonstrated for the control of this pest, and all that can be done is to record lines along which possible experiments might be conducted. For this purpose paradichlorobenzene seems worthy of some investigation, and indeed preliminary trials with this fumigant have

already been carried out. These, however, will have to be followed up before any definite expression of opinion is possible. It will be necessary to determine, firstly, just how effective that fumigant really is for this particular purpose, secondly, what are the minimum doses that can produce the required results, and, thirdly, just how safe it is for application to citrus trees. It may be added that paradichlorobenzene has been demonstrated to be a very useful fumigant for a number of soil-infesting insects.

The Queensland Fruit Fly.

The Queensland fruit fly (*Chætodacus tryoni* Froggatt) is frequently the cause of very considerable losses in citrus fruits, the losses occurring mainly in the late and early crops. The eggs are laid in small punctures in the fruit, and the maggots hatching therefrom feed voraciously, thus obviously rendering the fruit valueless for marketing. This highly destructive insect has already been dealt with in very considerable detail in Chapter VII. Its life history and control are discussed therein, and further reference to this pest is unnecessary in these notes as the full details can be obtained in the chapter mentioned.

The Pink Wax Scale.

This very conspicuous scale insect (*Ceroplastes rubens* Maskell) is a common pest throughout coastal Queensland on mandarins, oranges, and lemons, and it is also one of the pests most frequently associated with the mango. The fully developed scale is slightly more than ⅛ inch in length and is pink in colour. What is seen by the orchardist is not really the scale insect, but is the very heavy hemispherical coating of wax with which it has covered itself. Beneath that protective layer is the actual insect; the young insects belonging to this species do not of course possess this heavy protective covering, but they gradually acquire it during the process of growth. This species was originally described from specimens obtained in Australia, but, in spite of that fact, some authorities do not consider it to be a native of this country.

The feeding of this insect on the foliage of the trees which it infests is always associated with the presence of what is known as fumagine or sooty mould. The pink wax scale secretes a sweet sugary substance, and on this secretion there grows a black fungus which gives to the attacked tree an unsightly, dirty appearance. (This fungus is further discussed at the end of this chapter.)

Although the pink wax scale is not nearly so injurious to citrus as the red scale, it is nevertheless decidedly harmful, partly because of the actual weakening of the attacked tree and partly because of the production of the unsightly fumagine referred to. Steps should therefore be taken to control this pest, and for that purpose spraying with soda-wash or resin-wash can be recommended.

The spraying should be done at a time when large numbers of young insects are hatching out, because, as already indicated, the young scales have little or no protective covering, and they are then much more vulnerable than they will be at a later stage in their development.

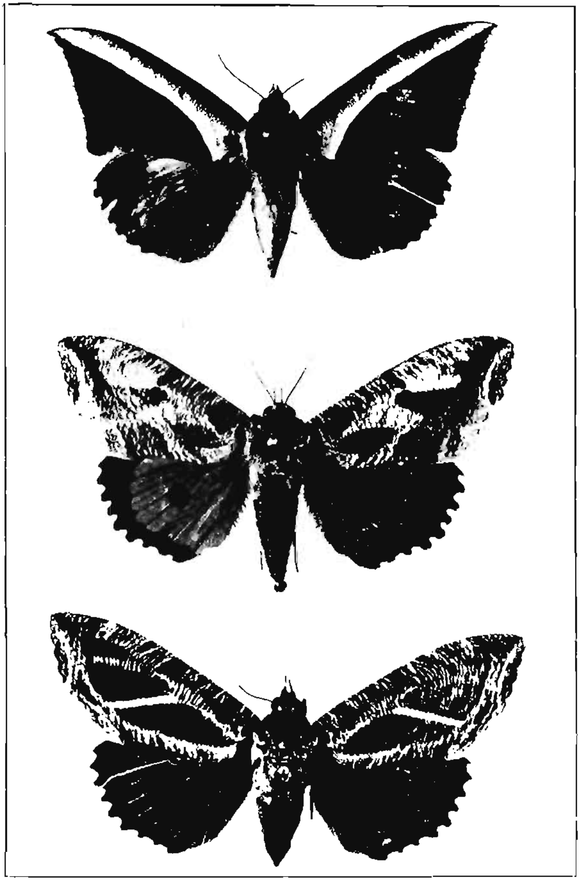
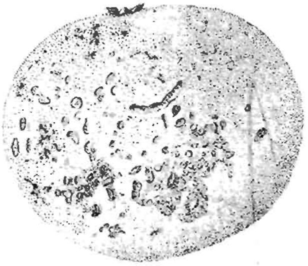


PLATE 21.- *Mænas salaminia* Fabr.
Argadesa materna Linn. (Male and Female.)



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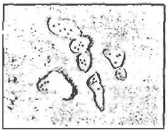


Fig 2.

J. W. Helmsing 1928.

PLATE 22.

Fig. 1. Black Spot on Orange. Fig. 2. Individual spots enlarged to show the black points of the pycnidia.

The preparation of resin-wash has already been dealt with in Chapter 3. The soda-wash may be prepared in accordance with the following formula:—1½ lb. of washing soda to 4 gallons of water. Only clean, fresh washing soda should be employed when mixing this spray, otherwise if old washing soda is used considerable damage may be done to the foliage of the treated trees.

Aphis.

Plant lice or aphids not infrequently attack the tender young twigs of citrus trees, and as a result of their feeding thereon the leaves curl up and the twigs shrivel and die if the infestation is allowed to continue. Frequently the attack is confined to a few twigs and it sometimes disappears quite suddenly. Should that not be the case, the plant lice may be controlled by spraying with nicotine sulphate.

Black Spot.

Black spot is a fruit disease to which most commercial varieties of citrus are subject. Old trees of the common seedling orange are probably the most seriously affected, and with these black spot is often responsible for considerable fruit disfigurement.

Symptoms.

An indication of the presence of black spot often overlooked is a somewhat scanty brown spotting of the leaves which may be present at various times throughout the year. The characteristic spotting of the fruit takes place when the latter is approaching maturity, and appears first as scattered, minute, pink or reddish-brown spots on the surface of the rind, usually with a definite and somewhat darker margin. These enlarge to a more or less circular area $\frac{1}{16}$ to $\frac{1}{4}$ inch in diameter. The central portion becomes shallowly depressed, and as the spot matures this region assumes a greyish colour, leaving only a narrow rim of the original brown.

If conditions are suitable, the fruiting bodies of the fungus causing the disease may be developed even in the early stages of spot formation. These make their appearance on the depressed areas in the form of minute, translucent, dome-shaped blisters which gradually darken until they become sooty black in colour. The small, grey depressed spot with a narrow brown rim, and studded on its surface with black points just visible to the naked eye, is quite characteristic of this disease. (Plate 22.)

Under conditions favouring the growth of the fungus, a diffuse browning may spread out from the margin of the spots, and, if the latter are numerous, coalescence and spreading may take place until a large proportion of the skin shows a brown and somewhat shrunken area over which are speckled the black points of the fruiting bodies. This latter effect is seen more especially on ripe fruit after storage, or on fruit which has fallen to the ground.

Cause.

Black spot is caused by a fungus (*Phoma citricarpa*) first described by McAlpine, the Victorian Plant Pathologist, in 1899. The fruiting bodies arise just beneath the surface of the depressed spots, and take the form of small flask-shaped receptacles known as pycnidia. It is the black walls of these pycnidia which show up as the characteristic black points mentioned above. From the inner lining of these structures are produced numerous minute, clear, oval spores which are extruded through an opening at the apex and thus serve to spread the disease. (Plate 5, fig. 7.)

The spotting resulting from an attack of this fungus does not usually appear until the fruit is commencing to colour, and becomes increasingly prevalent as the weather becomes warmer. For this reason greatest loss is sustained in fruit held for a late market.

Effects.

Although black spot does not usually penetrate beyond the outer region of the rind leaving the edible qualities unaffected, it nevertheless produces disfigurement sufficient to cause considerable reduction in price. After storage the spotting may spread, to give rise to a larger brown area of a more serious nature.

Spotted fruit becomes more easily attacked by blue mould and other rot-producing fungi, with the result that the keeping qualities are further impaired.

In the orchard it will be found that fruit affected with black spot will not hang on the tree when ripe. The loss from fruit falling off on this account is often considerable.

Control.

1. It is very noticeable that black spot is often present to a greater extent in an old orchard or one showing signs of neglect. For this reason steps should be taken by satisfactory manuring and cultivation to get the trees in a state of healthy vigorous growth. All dead and sickly wood should be pruned out.

2. As has been pointed out above, the fruiting bodies of the fungus may develop on fallen fruit, and these should therefore be carefully picked up and destroyed by fire or burying.

3. It is possible to control the disease by spraying with Bordeaux mixture. Experiments are now being conducted to determine for Queensland conditions the most effective times at which to make applications. In the meantime the following schedule is suggested:—

Bordeaux of 4-4-40 strength, or Bordeaux 4-4-40 + 1% of oil emulsion—

(1) As soon as the fruit have set;

(2) About one month to six weeks later;

(3) If black spot has been serious previously, another application just prior to the February rains.

PLATE 23.—Typical Melanose symptoms on leaf and fruit of the Orange. Also dead twig bearing pycnidia of *Phomopsis citri*.

Fruit on the sunny side of the tree is more subject to attack, and special attention should therefore be paid to this region.

Melanose.

Melanose is a trouble which is of rather frequent occurrence in some older orchards, where it may be of more serious consequence than black spot. The orange, mandarin, and lemon may all be affected.

Symptoms.

The disease appears on leaves, twigs, and fruit, though it is on the latter that it becomes most conspicuous. The characteristic lesions on the fruit consist of small brown, more or less circular dots scattered over the surface. The individual spots vary in size from minute specks up to about $\frac{1}{30}$ inch in diameter. They appear at first merely as a surface stain, but later become slightly elevated and somewhat fissured diagonally or round the margin so that a melanose-affected fruit is decidedly rough to the touch. The spots may be sparsely scattered or abundant, and are often seen to be arrayed in rings or lines (Plate 23).

When numerous a coalescence may take place so that a more or less continuous superficially fissured area is formed. In this latter condition melanose resembles to a certain extent both "Maori" and exanthema. A typical "Maori" orange, however, is usually of more uniform colouration, and is smooth to the touch, while a fruit affected with Exanthema, although rough usually, has the rind of the affected region more definitely hardened often with resultant splitting.

The spotting on the leaves resembles in general appearance that on the fruit except that it is black rather than brown in colour. Leaves badly affected may be puckered and otherwise deformed by the presence of the disease. Young twigs and water-shoots may be attacked in a similar manner, and if infection is severe leaf-fall may result.

Examined microscopically, the lesions are seen to consist of two or three layers of brown dead cells, which in the later stages become elevated by the development of a layer of corky tissue beneath. The unequal tensions resulting from the hardening of the surface layers, and growth of the tissue surrounding, results in the fissuring mentioned above.

Cause.

The symptoms displayed by this disease are the same as those of the melanose of Florida, which has been shown to be caused by the fungus *Phomopsis citri*. A fungus closely resembling this has been isolated from a stem-end rot of lemons and from dead twigs in Queensland, and it is probable that the two diseases are identical.

Some growers have been in the habit of designating the disease as "false" melanose. This name was applied by McAlpine many years ago to a similar disease then occurring in New South Wales, whose

presence be attributed to an entirely different fungus. The term "false" should be avoided when speaking of the disease which occurs in Queensland, since it often leads to confusion.

The fungus *Phomopsis citri* is not a very active parasite, and the melanose lesions formed by it are usually greatly restricted in extent, the fungus itself quickly losing its activity. It does, however, maintain a more active existence on dead twigs and branches, and it is here that the fruiting bodies are produced. These take the form of small depressed flask-like receptacles or pycnidia developed just below the surface of the bark, where they form minute pimple-like pustules the apex of which becomes split to liberate the spores developed within (Plate 23).

The spores are small, clear, oval cells which are extruded in a mass during damp weather. They are then washed by rain and dew from the dead twigs on to young and tender shoots or fruit, where they germinate if conditions are suitable, and infect the living tissue sufficiently to cause the spotting described above. The ring-like arrangement of the spots so characteristic of melanose is due to the lodgment of a number of spores in a water-drop, when they tend to spread out to the margin and there come to rest.

Examination of a tree badly affected with melanose will almost invariably reveal the presence of dead wood. A vigorously growing tree free from dieback is seldom affected. For this reason it is usually the older or neglected orchards that suffer most. It is only young shoots and fruit which are susceptible to infection. Growth which has hardened off is immune. Rain is necessary for the spread of the disease and the germination of the spores. This is always liable to occur in sufficient quantity during the spring and early summer months.

Control.

To control melanose the object is to reduce as far as possible the source of infection and to keep the young growth covered with a fungicide during its susceptible period.

1. Prune out all dead twigs and branches, and practise a system of fertilising and good cultivation with a view to inducing strong vigorous growth.

2. Spray with Bordeaux mixture of 4-4-40 strength, or Bordeaux 4-4-40 + 1% oil emulsion—

    (*a*) Immediately the fruit has set;

    (*b*) One month to six weeks later, or oftener if the weather conditions are exceptionally wet.

Scab.

Scab is a disease to which lemons are more particularly subject, their leaves, young twigs, and fruit being affected. During wet seasons most

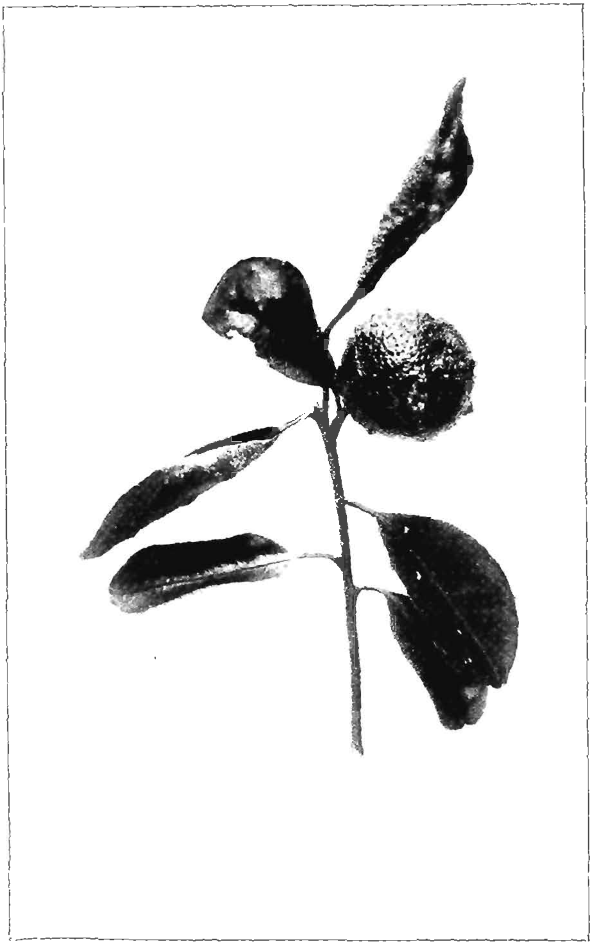


PLATE 24.—MANDARIN AFFECTED WITH SCAB.

varieties of mandarin may also be attacked, though in this case the foliage may suffer to a greater extent than the fruit. The sweet orange is apparently immune.

SYMPTOMS.

Only young growth is liable to infection. When the leaves commence to harden off and the fruit to mature they become resistant. The disease appears first on the young soft foliage as small, scattered, light yellowish green spots with a somewhat diffuse margin. The affected area becomes depressed from above downwards or *vice versa* so that a small conical projection is formed on the lower or upper surface of the leaf. At the apex of this elevation a small mass of brown corky tissue is developed which gives the characteristic scabby appearance to the leaf. The corky excrescences are also commonly formed on the leaf surface without previous leaf indentation. They vary in size from minute brown specks to rough wart-like scabs $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter. Large scabby areas may be produced from these by coalescence. Distortion and stunting often result owing to the inability of the leaf affected with scab to develop evenly (Plate 24). The lesions on the twigs and on mandarin fruit resemble in the main those on the leaf. On the lemon fruit the actual scabs are of much the same appearance except that they are as a rule somewhat larger. The effect is, however, often accentuated by the growth of the rind tissue surrounding a scab lesion into a prominent conical projection bearing the scab at its apex. Considerable malformation is produced by this means.

Scab is due to the presence of a fungus (*Sporotrichum citri*) whose fruiting stage appears as a delicate greyish mould covering the surface of young scabs.

CONTROL.

As pointed out above, the scab fungus infects only young immature tissue. Certain conditions of temperature and moisture are also necessary for its development. These conditions are always liable to occur in the Queensland spring weather, and if scab is present in the orchard steps should be taken to control it by means of spraying. The following applications may be made for this purpose:—

(1) Spray with Bordeaux mixture of 6-4-40 strength, or Bordeaux (6-4-40) + 1% oil emulsion, immediately before the new growth commences. This will help to clean up the fungus present on old scabs.

(2) Bordeaux of 4-4-40 strength, or Bordeaux (4-4-40) + 1% oil emulsion, at about the middle of the flowering period. This and the subsequent application are for the protection of young foliage and fruit.

(3) Bordeaux again as soon as the fruit have set.

(4) If the season is exceptionally wet it is advisable to give one or two further applications in order to keep the young fruit and foliage well covered.

It must be remembered that Bordeaux mixture may check the development of entomogenous fungi which materially aid in keeping down scale. It will therefore be necessary to pay particular attention to the control of these pests after Bordeaux has been used. If scab infestation is not serious or if the season is dry, lime sulphur, which does not possess these disadvantages to the same extent, may be substituted.

Blue Mould.

Blue mould rot of citrus fruits is caused by two allied fungi—*Penicillium digitatum* which forms an olive-green powdery spore coat over rotting fruit, and *Penicillium italicum* in which the spore mass is distinctly blue. The former is by far the chief source of rot in Queensland, and has been known to cause loss of 30 per cent. and over in long-distance consignments. This mould is sometimes referred to as the green mould to distinguish it from the blue form, but since remarks concerning the one are in general applicable to the other they will for convenience be treated together.

Symptoms.

The rot commences as a small, soft, water-soaked spot on the rind. The area enlarges, and when it has reached about an inch in diameter a white mould develops on the surface and extends out in pace with the softening of the rind by the fungus within the tissue. From the white surface mould are produced closely aggregated short upright hyphæ, which branch two or three times near the end. From each of the final branchlets are cut off chains of minute oval spores. (Plate 5, fig. 9.) It is the colour of these spores in mass which gives the characteristic appearance of the rotted fruit to which the disease owes its name. Finally the fruit may become broken down to a soft watery mass.

Contributing Causes.

The loss of citrus fruit in transport on account of blue mould rot has exercised the minds of orchardists throughout the world ever since the growing of these fruits began to assume a large commercial scale. The fungi causing the damage and the factors contributing to the development of the rot have been investigated in various countries, and these investigations in almost every case have led to three important conclusions which clearly point the way to the solution of the problem. These are—

(1) The species of *Penicillium* causing blue mould rot are relatively weak parasites and are unable as a general rule to penetrate the skin of a perfectly sound fruit. The blue mould fungus differs from the green in that the fungal threads making up the surface mould of the former may sometimes pass from a rotted to a healthy uninjured fruit with which it is in direct contact in the case. The first infection by means of spores must take place through wounds in the case of both species. It is a common sight to see perfectly sound fruit lying in a pack alongside one covered with green mould, clearly showing the immunity from infection of the uninjured fruit.

(2) The wounds occasioned during picking, carting, and packing serve as centres for infection by the blue mould spores which are present in the air of the orchard and packing house. Examination of twenty-one cases of oranges and mandarins arriving on the Brisbane markets showed that out of the 286 mouldy fruit present there were only 74 (or 25 per cent.) which did not show an obvious injury to account for the mould invasion, and very many of these consisted of fruit too mouldy for a primary cause to be ascertainable. The more common forms of injury were as follows:—Case bruises and cracks arising from poor packing, especially noticeable in connection with mandarins, 27 per cent.; punctures by long stalks, 18 per cent.; scratches and punctures of which the causal agency could not be determined with certainty, 16 per cent. The rest included miscellaneous injuries due to rubbing and pulling the button out, &c.

(3) The trouble can be to a great extent controlled by cleanliness and careful handling of the fruit to avoid bruising or otherwise injuring it.

Control.

Keeping the above facts in view, the following recommendations can be made for the control of blue mould.

(1) All waste fruit in the orchard and packing house should be collected at frequent intervals and destroyed by burning or burying, as it will otherwise serve for the production of countless millions of mould spores to contaminate the air in which marketable fruit has to lie.

(2) Picking fruit during wet weather should be avoided, as fruit gathered under moist conditions usually shows a much higher incidence of blue mould. Great care should be exercised during picking operations in order to ensure that no injury is given by the clippers, finger nails, &c. The fruit should be cut, not pulled, and long stalks must be avoided as these are a frequent source of injury to other fruit. It may be found advisable in many cases to make a double cut, removing the stalk close back by a second cut when the fruit is held in the hand.

The method of handling during the transference to the packing shed and subsequently should be such as to avoid bruises or mechanical wounds. The collecting boxes should be smooth and the fruit must be placed in them carefully.

(4) Citrus fruit are best allowed to cure for three to seven days before packing, and all those in which rot commences should be removed by frequent inspection. The grader, if used, should be of a style which does not bruise the fruit. Close attention must be paid to the picking over, and all blemished fruit should be discarded. Packing cases should be made of smooth wood, and care must be taken that the fruit are not rubbed against the sides or the pack made too tight, as bruising and cracking often arise from these causes, especially in the case of mandarins.

Wrapping the fruit serves to lessen blue mould loss by reducing the number of case bruises, and by enclosing any mouldy fruit so that the spores are not distributed throughout the case.

(5) Careful carriage of the consignment between packing shed and market is also advisable but not always within the control of the grower.

By giving attention to cleanliness and careful handling the loss due to blue mould may be reduced to an insignificant minimum.

Exanthema.

This disease is one apparently not dependent on the presence of parasitic organisms for its development, but is rather due to physiological disorders brought about by improper nutrition. Most varieties of citrus are subject to the malady.

Symptoms.

In the typical cases on young trees, symptoms commence with a flush of young succulent growth the branches of which are sometimes curved at the ends and usually bear abnormally large dark-green leaves. After a time the new growth assumes a slightly yellowish tinge, and there are developed along the branches dark-brown patches of a resinous appearance due to the deposition of a resin-like substance in the cells of the outer layers of bark. Definite longitudinal cracks may be formed from which is extruded the brown resin mass to form a rounded or fissured excrescence. (Plate 25.) Gum pockets having the appearance of a rounded blister may be formed on the succulent growth by the accumulation of the brown gummy secretion in certain spots between the wood and bark, the latter being forced out in the process. Multiple buds and very angular stems are often characters associated with branches exhibiting this disease. The leaves of the affected terminals usually drop, leaving the bare brown branches showing up conspicuously. Later these die back and are invaded by various saprophytic fungi. A dark-brown superficial marking somewhat similar to that occurring on the shoots may be present on the rind of the fruit borne by a diseased tree. These patches often have the appearance of being formed from aggregated spots. The latter are slightly raised and cracked, which makes the affected area rough to the touch. The presence of this fruit discolouration is usually accompanied by a hardening of the skin, with a consequent restriction in growth, which often leads to cracking.

Contributing Conditions.

Exanthema usually makes its appearance on very light sandy soils lacking in humus, such as are to be found in some of the coastal citrus areas. The use of this type of soil would appear to be one of the main causes of the occurrence of this disease so far as Queensland is concerned. Heavy rainfall followed by a dry spell; poor drainage; and the excessive use of organic nitrogenous manures are factors also stated to favour the development of exanthema.

Plate 25.—Exanthema on Orange.
From a water-colour drawing by I. W. Helmsing.

CONTROL.

All dead and dying wood should be removed by thorough pruning.

The soil conditions should be improved as far as possible by judicious manuring (avoiding excessive use of organic nitrogen), and by the ploughing in of green crops to better the physical condition and increase the humus content. Artificial drainage should be practised when necessary.

Some growers have obtained benefit from spraying with Bordeaux mixture, the copper sulphate in this case appearing to act largely as a tonic. The bluestone may also be applied by spreading it on the ground round the tree. In this case ½ to 1 lb. per tree is used, depending on the size of the tree.

Dieback.

Dieback is a condition which may sometimes be confused with exanthema. It is characterised by the death of twigs and small branches on the outside and more especially on the top of the tree. This trouble differs from Exanthema in the absence of resinous exudation, gum pockets, and multiple buds, and in the fact that the affected branches are usually of stunted rather than of vigorous growth.

Pink pustules of a fungus (*Glœosporium sp.*) are usually scattered over the dying twigs. This fungus commonly attacks only those branches which are in a weak or dying condition owing to the tree having insufficient vigour to support them.

The trouble appears in neglected orchards and on poor land, more especially if a hard impervious subsoil is causing bad drainage.

The treatment should follow the lines of improving the growing conditions of the tree by good cultivation, manuring, and if necessary drainage, when the trouble will be found to disappear.

Collar Rot.

Collar rot or foot rot is the commonest and the most destructive of the several forms of gumming disease to which citrus trees are subject. Lemon trees or the lemon stock on which other varieties are worked are most susceptible. The mandarin and sweet orange are also sometimes affected.

SYMPTOMS.

The disease usually occurs at the base of the main trunk, where it appears as a darker, somewhat water-soaked area not very definitely marked off from the surrounding healthy bark. There is usually a puncture or slit towards the centre from which gum-drops have exuded. The bark over the diseased region may be easily lifted, and between this and the wood is found a slimy, clear, gum-like substance. The wood below the diseased bark exhibits a brown discolouration, which, however, does not usually penetrate for more than ⅛ inch. The margin between this and the healthy tissue is especially distinct and shows as a narrow band of slightly darker brown.

A collar rot of any size will make its presence evident by a yellowing of the foliage and dieback. This will often take place only on the one or more branches which arise from the same side of the trunk as is affected by the rot. Eventually the branch may die out completely. Should the lesion extend round the trunk the whole tree may be ringbarked and die.

CAUSE.

The organism recorded as causing foot rot in Queensland is a fungus known as *Fusarium limonis*. It is, however, probable that other fungi are at times responsible for the trouble.

CONTROL.

The organisms concerned in collar rot will not penetrate healthy living bark, so that a wound of some form must be present before infection can take place. It is therefore important to avoid any injury during cultivation.

Badly drained soil and water accumulation round the crown are conducive to gumming and should therefore be avoided.

A close watch should be kept for the appearance of collar rot lesions. When caught before they have advanced too far the disease can be cured by surgical methods. The soil should be opened up away from the crown and main roots so as to expose these to the sun and air. The diseased bark and wood must then be carefully removed by cutting or scraping with a sharp instrument well back into sound tissue. The excised pieces should be carefully collected and burnt. If any of the roots are badly affected they are best removed entirely. When the trunk has been thoroughly cleaned of all diseased tissue the wound should be painted with Bordeaux paste.

Armillaria Root Rot.

The tree affected by this disease exhibits symptoms similar to those associated with collar rot. There is usually a yellowing of the foliage of the whole tree or on one or more branches, together with more or less dieback. As the fungus responsible for this rot attacks also a number of other fruit-trees, the full description of the disease, together with recommendations for treatment, have been left to Chapter XIII.

Fumagine or Sooty Mould.

Sooty mould cannot be considered as a definite disease to the same extent as may the citrus troubles previously described, but since it is of conspicuous appearance and to a certain extent detrimental to the tree affected a short description is here given.

SYMPTOMS.

The tree affected with fumagine is conspicuous on account of the black sooty deposit covering the foliage and often the fruit. It is

common to see whole trees or even entire orchards exhibiting the dirty black appearance due to the presence of this mould. The fruit may be rendered so unsightly that scrubbing becomes necessary.

Cause.

An examination of the leaves will show the sooty appearance to be due to a thin, black, superficial film, which may be easily scraped off in flakes. This film is formed by the close interlacing of the dark mycelial filaments of a fungus known as *Capnodium citricolum*. This fungus is not a plant parasite, but lives on the sugary substances which become scattered over the leaves after secretion by certain scale insects. Of these latter the chief ones concerned are the pink and white wax scales and to a certain extent the Lecanium or soft scales.

The fungus is entirely superficial in its growth and therefore does not directly injure the tree. The presence of the covering of mould will, however, eventually tend to weaken the tree, as assimilation will be checked by the exclusion of light and by the blocking up of the breathing pores of the leaf.

Control.

To get rid of sooty mould it is necessary to destroy the scale insects on whose secretion the fungus is dependent for its existence. This should be done by suitable spraying or cyaniding, when the fumagine will be found to gradually disappear. If it is desired to remove the mould quickly after the destruction of the scale, the trees may be sprayed with a thin paste made by boiling flour in water. This will form a skin over the leaf which when it dries will flake off and carry away the mould in the process.

CHAPTER IX.

PESTS AND DISEASES OF BANANAS.

Banana-growing in Queensland is unfortunately probably more handicapped by the incidence of pests and diseases than any other branch of fruit culture in this State. The entomologist has to handle such extremely serious and difficult pests as the banana weevil borer and the banana thrips: less serious but still important sources of loss that come within his province are such pests as the fruit-spotting bugs, fruit-eating caterpillars, and the banana fruit fly. There are quite a number of other insect enemies of the banana, but they are all, at least at present, of trifling importance to the grower, and reference need not be made to them in these notes, except in the case of the banana aphis. The latter is of no consequence so far as actually weakening the plant by sap-sucking is concerned, but it is of first-class importance as the insect vector of bunchy top.

Pathologically the position in banana-growing is just as acute as it is entomologically, and in these notes considerable attention is accordingly given to such diseases as bunchy top, leaf spot, and Panama disease. Dry rot, stem-end rot, anthracnose, cigar end, and squirter are also discussed as minor sources of loss.

The banana weevil borer has been the subject of an exhaustive investigation by J. L. Froggatt, and readers who wish to acquaint themselves with all aspects of the borer problem should consult the bulletin prepared by that investigator. Banana thrips has also received considerable attention and a bulletin thereon has been written by Girault, and here again the reader may consult a much more extensive fund of information than can be given within the pages of a handbook such as this. Girault's investigation was followed by further work by Froggatt, dealing more particularly with the question of the field control of the banana thrips.

Bunchy top has also been the subject of a large-scale investigation, which in this case has been a co-operative project, financed partly by the Department of Agriculture and Stock of this State. A very full account of that investigation will be found in the bulletin prepared by C. J. P. Magee.

The Banana Weevil Borer.

The banana weevil borer (*Cosmopolites sordida* Chevr.) is without doubt the most destructive insect enemy of the banana plantations of Queensland. Not only is its attack frequently one of great severity, but there is also every reason for believing that few, if any, districts in this State are free from infestation. The available evidence apparently indicates that this species is not a native of Australia, but it is now a

PLATE 26. BUTT OF BANANA PLANT ATTACKED BY BANANA WEEVIL BORER.

matter of extreme difficulty to indicate with any degree of confidence the native home of this very destructive weevil. It has been recorded from Africa, Australia, Ceylon, Fiji, India, Java, Mauritius, New Hebrides, Philippines, Raratonga, Samoa, South America, and the West Indies.

Nature of Injury.

The damage to the banana plant in the case of this species is caused entirely by the grubs of the weevil borer feeding in the tissue of the attacked plant. (Plate 26.) The grubs hatch from eggs laid by the beetles, and in feeding in the bulb or corm of the banana plant they tunnel through the corm to such an extent, in the case of severe infestations, as to seriously weaken the plant. In its weakened condition both the quantity and quality of the fruit produced by the infested plant are very appreciably reduced, and thus the growers suffer very severe losses. This reduction in yield and quality is particularly noticeable when the plant is growing under unsuitable soil conditions, and is also much in evidence during an unfavourable season characterised by unusually low rainfall.

Plants Attacked.

The banana weevil borer in Queensland has never been found attacking plants other than those belonging to some species of banana. The different varieties of cultivated bananas grown in this State—i.e., Cavendish, Dacca, Gros Michel, Lady's Finger, Plantain, and Sugar—do not appear to differ in any degree with respect to their susceptibility to attack.

Life Cycle Stages.

The usual four life-cycle stages are met with in this pest—namely, the egg, grub, pupa, and adult. The egg is the stage of incubation, the grub of active feeding and accompanying rapid growth, the pupa of transformation, and the adult of reproduction.

The elongate oval egg (Plate 27, fig. 1) measures roughly $\frac{1}{12}$ inch in length and is pearly white in colour when first laid; as the incubation period advances certain changes, however, can be noted in its colour, but these changes need not be dealt with in the present notes.

The full-grown grub or larva (Plate 27, fig. 2) measures about $\frac{1}{2}$ inch in length and is normally distinctly curved in appearance. It is a somewhat bulky object with a creamy-white body and a reddish-brown head. Other features worthy of mention are the fact that it is legless, and that certain of its body segments are very much swollen, thus giving it the bulky appearance already mentioned.

The pupa (Plate 27, fig. 3) is about the same length as the grub, which it also closely resembles in colour when newly formed. Even a casual examination of this stage of the insect's life cycle will disclose the fact that the wings and legs of the future beetle are distinctly visible in the pupa.

The adult (Plate 27, fig. 4) is a typical weevil possessing a very prominent trunk or proboscis. It is black in colour, measures roughly ½ inch in length, and, like many weevils, its skeleton or outer shell is extremely hard.

LIFE HISTORY AND FEEDING HABITS.

The eggs of this beetle are laid singly, the spot chosen for egg-laying being in the plant at or near ground-level. A small curved chamber is formed in the plant tissue by the female beetle, and therein the pearly-white egg is deposited. The incubation period of the egg varies, but according to Froggatt it may be regarded as averaging eight days during the warmer months of the year; in midwinter, however, the incubation period has been prolonged to as many as thirty-six days.

It is worth while mentioning the fact that egg-laying in the case of this weevil occurs right throughout the year but with varying intensity, the maximum activity in egg-laying being displayed in spring and autumn.

On hatching from the egg the grub commences its career of destruction, and if an infested corm is examined it will frequently be found to be tunnelled through and through, this tunnelling being accompanied by the evil effects already referred to in an earlier paragraph, namely, a serious reduction in the quantity and quality of the fruit produced. This honeycombing of the corm would not, of course, be the work of one grub; as many as thirty-five grubs have been found in a single corm.

It has generally been found that, in the case of banana weevil borer infestation, the attack is confined to the underground portion of the plant and to but a few inches above ground-level; however, in cases where the stem has been left standing after the cutting of the bunch that it has thrown, infestation of the stem may be very extensive, and indeed it may be attacked throughout practically its whole length.

The grub continues feeding within the tissue of the plant for some considerable time, the actual duration of this stage, as indeed is the case in all the others, being influenced very greatly by the prevailing temperature. Froggatt has found that in summer growth may be completed in two weeks, whereas in winter quite twenty-three weeks may be required for the completion of this stage in the insect's development. During its period of growth the grub moults several times, moulting being necessitated by the fact that the skin of insects does not grow but will only stretch to a limited extent. When its growth is on the verge of completion the grub diverts its tunnel towards the outside of the corm, so that there may be but a very slight barrier between the newly formed beetle and the outer world.

The grub then transforms to the pupa at the end of its feeding tunnel, and it does so without forming the fibrous cocoon that is so frequently present in this type of beetle. The usual transformation

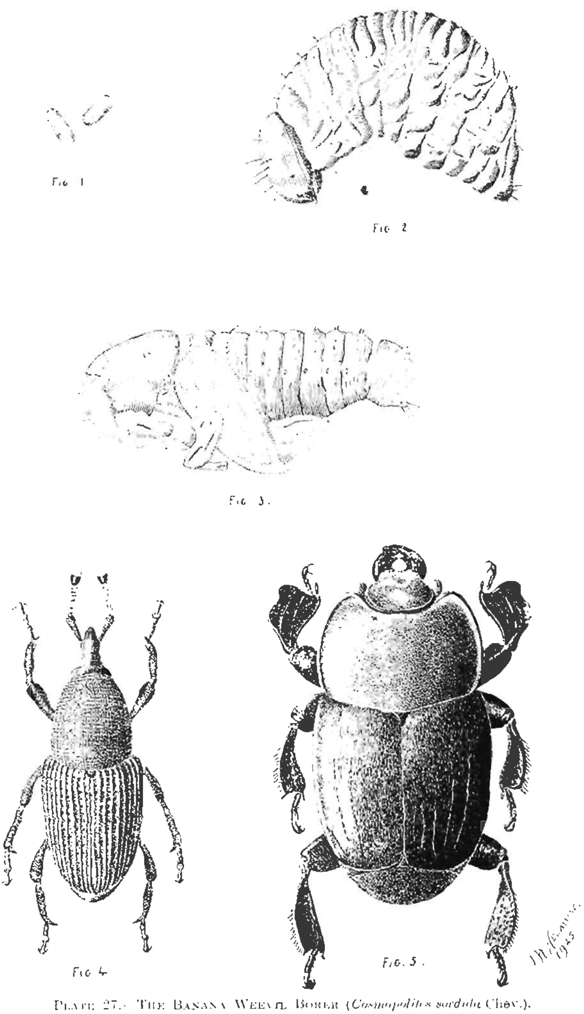


PLATE 27.—THE BANANA WEEVIL BORER (*Cosmopolites sordida* Chev.).
Fig. 1. Egg. Fig. 2. Larva or Grub. Fig. 3. Pupa. Fig. 4. Adult Borer.
Fig. 5. Adult of *Plæsius javanus*, predator on the Borer. Magnified 4 diameters.

processes take place, and as a result thereof the beetle or weevil appears in a little over a week. Here again there is some considerable variation, for in winter as many as eleven days have been spent in the pupal stage, whereas in summer it has been as short as four.

The period that elapses between the laying of the egg and the emergence of the beetle is somewhere in the vicinity of seven weeks on an average, but, as already indicated in the discussion of the various stages of the life cycle, that figure fluctuates very considerably with such factors as temperature.

The newly formed beetle does not leave the pupal chamber for a few days but remains resting quietly therein hardening and darkening its skeleton, and having done so it then eats its way out into the soil, feeds, mates, and thus reproduces its species and commences a new life cycle.

Control Measures.

The life history as outlined above should clearly indicate that there is little hope of successfully employing either sprays or fumigants against this serious pest. All stages in its life cycle, except the weevil itself, are very securely entrenched behind a most effective barrier of plant tissue, and hence in employing artificial control measures attention must be confined to the beetle itself.

In practice it has been found that the beetles are attracted to baits, and it has further been demonstrated that the beetles so attracted will be killed if the baits are dusted with Paris green. If the two operations of trapping and killing are combined in this way, the very laborious business of regularly visiting the baits and killing the beetles that have been attracted thereto will be eliminated.

Suitable baits are supplied by the banana plant itself, and growers wishing to combat this pest by baiting have a choice of several systems.

Portions of the corm may be cut off and placed on the ground either inside or close to the banana stool. The freshly cut surface of the sliced corm is dusted with Paris green, which has previously been diluted with flour at the rate of one part of Paris green to six parts of flour. The slices of corm treated as described are then placed in position with the dusted surface downwards and are covered with trash. The object in covering the baits with trash is partly to produce the degree of darkness that is so attractive to the beetles and partly to prevent unduly rapid drying out of the baits which would thus become relatively unattractive.

A second system that is much in favour consists of cutting out a plug of tissue in old butts by means of the sucker pruning blade. The cavity thus formed is dusted with the poison mixture and the plug is then replaced. The cut surface of the old butt is also dusted.

The third system of baiting is the one that is at present most in favour, and it consists of dusting the freshly cut surface of the old butt after a deep groove has been cut therein by means of a cane-knife. The

whole of the cut surface as well as the wedge-shaped piece of tissue removed from the groove is dusted with the poison mixture, and the wedge is then replaced in the groove.

In the experimental work conducted by Froggatt in connection with the control of this pest, numerous poisons were tested out in conjunction with the baits. Very appreciable kills were obtained with quite a number of the substances employed, but it was found that Paris green was the most satisfactory of those handled, firstly because it gave a very high percentage of mortality and secondly because it was very rapid in its effects. Hence the Department strongly recommends its use as the most suitable poison to employ in conjunction with the baits.

Attention has so far been confined to the prospects of controlling this pest by the use of poisoned baits, but that is by no means the only weapon available in the campaign against the banana weevil borer, for strict observance of plantation hygiene will be productive of decidedly beneficial results.

Plantation hygiene necessitates the digging out of badly infested stools. Such stools are no longer profitable, and as they merely serve to intensify infestation their loss will not be felt by the grower. Where a stool is but slightly infested, the treatment required is not nearly so drastic and it will be sufficient if the old corms are removed. These corms should be carefully sliced up into thin pieces and any stems removed should be chopped in half.

Stems from which the bunches have been cut should be chopped off close to the ground, and then split in halves in order to facilitate the rapid drying out and decay of the tissue, which will thus be rendered unattractive to the borer.

Prevention of Infestation.

It has been demonstrated that the most frequent means by which new plantations become infested with the banana weevil borer is through the use of infested suckers in planting up such new areas. Infestation may also occur by beetles being carried down in flood waters from higher infested levels to lower uninfested areas, and also by beetles crawling in from an adjacent badly infested plantation. Flight also plays some part in the dispersal of this pest, but it is at present regarded as playing only a very minor part in infestation.

Flight cannot be controlled, and obviously little can be done in dealing with flood waters, hence efforts to prevent infestation or intensification of infestation must be largely confined to dealing with imported suckers and the crawling beetles.

To deal with the possibility of infestation in imported suckers, the following departmental recommendations have been made. Firstly, the digging of suckers or corms should each day be restricted to the quantity that can be planted the following day. Secondly, every corm or bulb that has been dug out should be carefully examined for traces of borer

PLATE 28. BANANA FRUIT SHOWING "RUST" DUE TO THRIPS ATTACK.

infestation, and it has been found that this is best accomplished by carefully paring off a thin slice of plant tissue. It is desirable that this slice be removed as far up as it is practicable to do so without inflicting injury to the eye. Paring off this thin slice will accomplish a twofold object; firstly it will eliminate any eggs that may have been laid in the corm, and secondly it will expose borer tunnels that may be present. All corms showing the presence of borer tunnels should be destroyed. Finally, having selected the suckers in accordance with the preceding recommendations, these should be placed on a cart or slide and removed to the new area with the least possible delay. If they are allowed to remain overnight in an infested plantation, the precautions of paring and destroying tunnelled corms will in all probability be rendered of little value by reinfestation of the suckers while waiting overnight for removal.

The danger of heavy infestation of clean new areas adjacent to old infested ones is very appreciable, and if such sites have to be selected for new banana plantations it is desirable to lay rows of baits between the new and the old areas, in order to minimise as far as possible the migration of beetles from the one to the other.

The policy to be adopted in the fight against the banana weevil borer may be summarised by saying that the chief objective is firstly to endeavour to keep new areas clean by adopting the precautions already detailed, and secondly, when infestation has occurred, to endeavour to minimise its effects by baiting the beetles with Paris green.

Possibility of Biological Control.

The Department of Agriculture and Stock has devoted a considerable amount of attention to the possibility of controlling this pest by the introduction from overseas of some of its natural enemies. Between the years 1921 and 1926 a number of colonies of the predatory Histerid beetle *Plæsius javanus* Er. (Plate 27, fig. 5) were introduced from Java and liberated on suitable plantations in Queensland. Definite evidence of the establishment of that beneficial insect has not yet been obtained.

More recently Froggatt visited Java and inquired into the whole question of the control of the banana weevil borer in that country, paying particular attention to its control by natural enemies. Arising out of that visit, further large colonies of *Plæsius javanus* were imported to Queensland and are at present being handled in captivity in quarantine. Colonies of a predaceous Leptid fly, *Chrysopila ferruginosa* Wied., were also obtained, and after undergoing the usual quarantine period a colony of this beneficial insect was liberated in the Cooran district.

It should be clearly understood that, in the case of this pest, the biological control work is still in the experimental stage, and, even if the two insects just discussed should become permanently established in this State, some considerable time, extending into several years, must elapse before there is any possibility of their becoming sufficiently

numerous and widely distributed to appreciably reduce infestation. Growers are therefore urged to continue to carry out the control measures recommended in earlier paragraphs. They can rest assured that, should the present experimental work in biological control show signs of success, they will be immediately advised to that effect.

The Banana Thrips.

The banana thrips (*Scirtothrips signipennis* Bagnall) is a very small and insignificant insect which has for many years been responsible for the serious banana-skin condition known as "rust" or "colour." Centres of infestation occur in various localities in coastal Queensland. from Cairns in the far north to banana-growing districts south of Brisbane. In recent years particularly serious outbreaks have occurred in the Innisfail and Gympie districts.

Nature of Injury.

The term "rust" has been applied to attacked bananas because of the characteristic injury produced by the feeding of the larval and adult thrips on the skin of the fruit. Infestation commences at points of contact on the fingers, particularly at the base of the hand. The injured fruit then acquires a typical reddish-brown appearance with a somewhat roughened surface (Plate 28). This discolouration and roughening of the skin may be confined to a relatively small area at the base of the hand, but in severe attacks it may involve practically the whole of the skin of the fruit. Furthermore the skin may subsequently become quite extensively cracked. Where infestation has not been unduly severe, thrips attack does not render the fruit less palatable, although it undoubtedly gives it a much less attractive appearance and thereby appreciably reduces its market value. When the whole surface of the fruit or the greater part thereof is involved in severe discolouration and roughening, the quality of the fruit is, however, decidedly impaired, and cracked fruit with exposed pulp is obviously unsuitable for marketing.

Life Cycle Stages and Life History.

The very small eggs of the thrips are laid in the skin of the fruit, generally in tissue on which colonies of the adults have established themselves where the fruit are touching at the base of the hand. Egg-laying takes place in punctures made by means of the saw-toothed ovipositor with which the female is equipped (Plate 29, fig. 2d). Eggs are similarly deposited under the leaf-sheaths, where adults also very frequently form colonies. According to the life-history studies carried out by Girault, these eggs hatch after an incubation period of about a fortnight, which is surprisingly long in view of the fact that the duration of the subsequent larval and pupal stages is only about one week in each case.

The larvæ on hatching out feed in colonies in association with the adults, these colonies as already indicated being found beneath the leaf-sheaths and on the fruit at various points of contact. The larvæ become

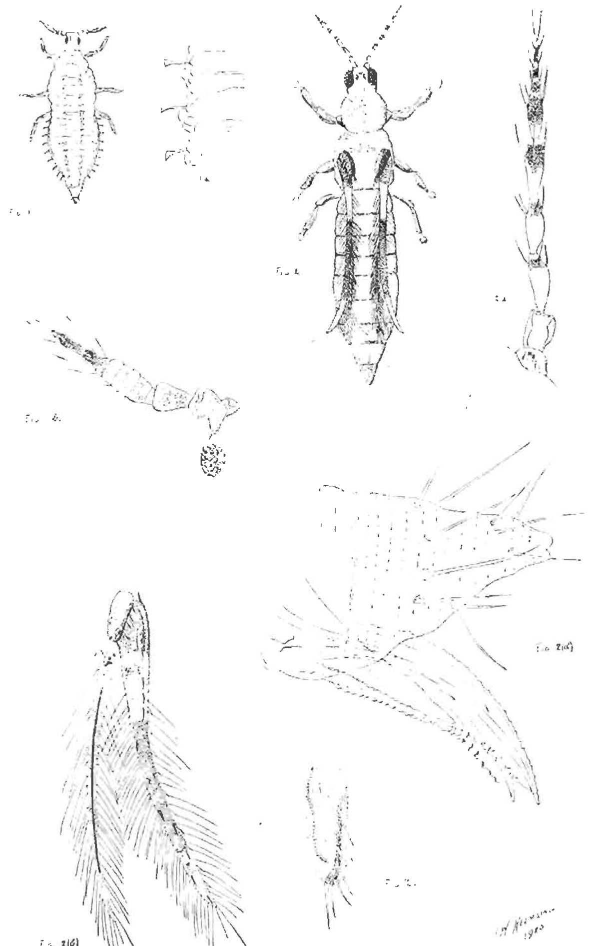


Plate 29.—The Banana Thrips (*Scirtothrips signipennis* Bagnall).

Fig. 1. Larva, × 45. Fig. 1*a*. Portion of side of abdomen of larva, × 210. Fig. 1*b*. Antenna of larva, × 210. Fig. 2. Adult female, × 45. Fig. 2*a*. Antenna of adult female, × 210. Fig. 2*b*. Wings of female, × 90. Fig. 2*c*. Scale over base of wings, × 180. Fig. 2*d*. Apex of abdomen of female, showing saw-toothed ovipositor, × 295.

full-grown in about a week and are then about $\frac{1}{25}$ inch in length and are white in colour. They pass through the usual series of moults: a young larva is illustrated on Plate 29 in figure 1.

The full-fed larva pupates either on the plant or in the soil and a week later the winged adult appears (Plate 29, fig. 2). The adult is a delicate yellow insect bearing two pairs of typically fringed wings: in size it is very slightly larger than the full-grown larva.

Thrips infestation may be observed in every month of the year, but it is at its lowest ebb during the winter months. With the approach of warmer weather in September, numbers increase appreciably, and the peak of infestation is reached in January and February.

Control Measures.

Before considering the question of the control of this pest when it actually occurs on a plantation, it is perhaps desirable to point out the necessity for taking every precaution to prevent its establishment where that has not already taken place on a plantation. With this object in view, suckers, if they have to be brought in from another plantation, should where possible be obtained from one in which thrips do not occur. Infestation is now, however, so widespread throughout coastal Queensland that it will be difficult indeed to find a "rust"-free plantation from which to draw supplies. Hence most growers will have to obtain their supplies of suckers from infested plantations. When doing so, the soil on the bulbs should be removed as thoroughly as possible, and they should then be pared so as to remove a thin slice of tissue. Finally the top should be removed as close down as possible. A question that has frequently been raised is the possibility of dipping suckers in a solution that will kill the thrips and thus ensure a supply of clean suckers. There are, however, a number of difficulties which appear to render such a desirable procedure impracticable, at least in the present state of knowledge.

Where infestation occurs attention should be paid to plantation hygiene, and, as in the case of banana weevil borer infestation, stems from which bunches have been cut should be chopped down close to the ground, and then split open to hasten the drying out of the tissue, which will thus cease to be attractive to the thrips for feeding or breeding. The removal and destruction of tip fruits is also desirable for similar reasons. Hoeing in the vicinity of the banana plant will lead to the exposure and destruction of pupæ and newly transformed adult thrips, and will thus be productive of much good.

Finally consideration must be given to the possibility of effectively controlling this pest by the use of insecticides. Pyrethrum powder mixed with sifted wood ashes in equal portions was tested as a dust in the 1924 investigations, 1 lb. of the pyrethrum being sufficient to dust 230 bunches. Girault recommended that the treatment be repeated at least four times at intervals of nine days. In 1926 Froggatt carried out

field trials in the Innisfail and the North Coast districts, to test the value of calcium cyanide dust, in the hope of obtaining a more deadly dust with the power of rapidly killing practically the whole thrips population on dusted bunches. A very high percentage of kill was obtained and no damage was done to the treated fruit. Banana-growers in some cases have, however, complained of injury to treated fruit, and accordingly further field trials have recently been instituted to place the insecticidal treatment of this pest on a thoroughly satisfactory basis.

Fruit-spotting Bugs.

In the Byfield section of the Rockhampton district, considerable losses have been caused by the feeding of two species of bugs, namely, *Pendulinus fuscescens* Dist. (Plate 30, fig. 2) and *Pendulinus lutescens* Dist. These Coreid bugs attack the fruit, and as a result very characteristic dark, circular, depressed areas are formed in the vicinity of the feeding punctures on the skin of the injured fruit (Plate 31). At the centre of these depressed areas there is a pronounced raised spot. Fruit at all stages of maturity may be attacked, but the results of the puncturing vary in their intensity. If the fruit is attacked while it is still very small, the skin will generally split across the centre of the depression surrounding the original puncture (Plate 32), and such fruit is obviously of little or no value for marketing. Splitting does not take place when the attack is confined to more mature fruit, and the infestation consequently is not quite so serious in its effects, although it is without doubt at least a serious blemish that renders the fruit unattractive in appearance.

The injury to fruit is inflicted by both the nymphs and the adult bugs, and is most pronounced in late summer and autumn. *Pendulinus lutescens* Dist. is thought by Froggatt to be the more destructive of the two species. It occurs at many centres throughout coastal Queensland, ranging from Cairns in the North to Brisbane in the South. It is therefore rather curious that its destructive activities should have caused concern in only one banana-growing district in the State. Fruit showing apparently identical injury has, however, been seen in small quantities in the Glastonbury section of the Gympie district. It is, of course, impossible to say whether the Glastonbury fruit was attacked by the species now under discussion or by some other bug.

Control Measures.

Little definite information can at present be given with respect to the control of these pests, and they should accordingly form the subject of an investigation whenever a suitable opportunity occurs for doing so. Sharply jarring the bunch, over the lower portion of which a bag of mosquito netting has been previously slipped, will cause the immature nymphs to fall into the trap thus formed, and also induce the adults to fly downwards into the netting. The bugs collected in this manner can then be subsequently destroyed, and it may be that such a method

Fig. 1 × 225

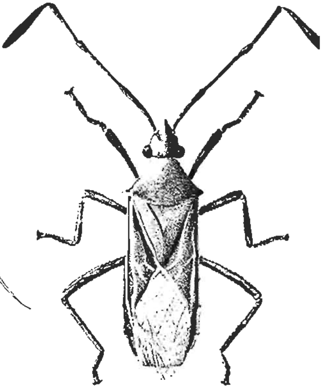


Fig. 2 × 4

Fig. 3 × 1½

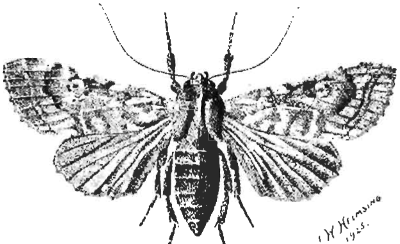


Fig. 4 × 1½

PLATE 30.

Fig. 1. Anal segments of male of *Scirtothrips signipennis* Bagnall, showing genitalia, × 225. Fig. 2. Imago, *Pendulinus fuscescens* Dist., × 4. Fig. 3. Larva, *Tiracola plagiata* Wlk., × 1½. Fig. 4. Imago, *Tiracola plagiata* Wlk., × 1½.

PLATE 31.—DAMAGE CAUSED BY FRUIT-SPOTTING BUGS.

of attack will prove sufficiently effective to be economically practicable. In the absence of anything better it is at least worthy of a trial on infested plantations. Any field investigation that is carried out should also test the possibility of successfully using stockinet covers to protect the fruit from attack. Preliminary evidence in favour of this procedure has already been obtained.

Some attention has been given to alternative host plants of these bugs, and when their host relationships are more fully known some useful information may be available on which further effective control measures can be based.

Fruit-eating Caterpillars.

Several species of fruit-eating caterpillars attack the skin of the fruit, while some feed first on the skin and subsequently penetrate to the pulp, on which they then feed. The skin erosion at best gives an unattractive appearance to the fruit, and if it is followed by cracking the fruit becomes valueless. Where the pulp is attacked the fruit is of course a total loss.

Quite a number of species of caterpillars are responsible for this type of damage, and in some seasons one species at least may be so abundant as to inflict very severe losses. Such an epidemic occurred in 1927, when enormous numbers of the caterpillars (Plate 30, fig. 3) of the Noctuid moth *Tiracola plagiata* Wlk. (Plate 30, fig. 4) migrated from the weeds on which they were feeding on the edges of the banana plantations. They then attacked the foliage and fruit of the bananas, and in the course of a few weeks they inflicted very severe losses on many plantations (Plate 33).

Where there is evidence of the recurrence of such an attack, serious consideration might be given to the use of poison bran baits, which would intercept at least a very large proportion of the caterpillars before they reached the bananas. The migrating caterpillars that fed on the bran baits scattered on the ground would rapidly succumb to the effects of the Paris green contained in the baits. The preparation of these baits is discussed in the chapter dealing with insecticides.

Banana Fruit Fly.

Several fruit flies attack bananas in this State, the species that is entitled to the unwelcome distinction of being called "the banana fruit fly" being *Chætodacus musæ* Tryon (Plate 34). This fly appears to be responsible for the injury to bananas grown north of Cardwell, and from that district right up to Cairns it may be regarded as a pest of some importance. In Southern Queensland fruit-fly infestation is caused by the Queensland fruit fly (*Chætodacus tryoni* Froggatt) and the boatman fly (*Rioxa musæ* Froggatt), most of the injury being inflicted by the first-mentioned species. Fruit-fly losses in the Southern banana-growing districts are, however, of but very slight importance, largely

because the Queensland fruit fly, the chief culprit in Southern areas, generally confines its attacks to mature fruit produced in summer. The banana fruit fly, on the other hand, has frequently been found by Froggatt attacking immature fruit that is only two-thirds developed, and hence it assumes some considerable degree of importance.

Life History.

This pest lays its eggs (Plate 34, fig. 1) in the skin of the fruit, and the maggots (Plate 34, fig. 2) hatching therefrom feed in the pulp, thus producing disintegration of the tissue and rendering the fruit valueless. When full-grown the maggots leave the infested fruit and form their brown puparia (Plate 34, fig. 3) in the soil. The reddish-brown flies (Plate 34, fig. 4) subsequently emerge and carry on the work of infestation. Detailed information is not yet available with respect to the duration of the various life-cycle stages of this pest. It has been bred from the native banana (*Musa banksii*), but so far no other host records have been obtained, although efforts have been made to do so.

Control.

The banana fruit fly has not been the subject of such detailed study as has been devoted to its relative the Queensland fruit fly, but nevertheless some information of value is available with respect to its control.

Firstly strict attention should be paid to plantation hygiene, and consequently all discarded or infested fruit should be collected and disposed of in such a manner as to preclude its giving rise to a brood of flies. The best means of attaining this object can be most appropriately determined on the plantation itself. Various means whereby infested fruit may be disposed of have already been discussed in an earlier chapter when dealing with the Queensland fruit fly.

A further useful procedure is to eliminate, so far as it is practicable to do so, all wild banana plants growing in or in the immediate vicinity of cultivated banana plantations. Unless these wild banana plants are destroyed they will quite undoubtedly serve to breed up flies to infest the fruit on which the banana-grower depends for his existence.

For many years stockinet has been used in North Queensland to protect the banana bunches from fruit-fly infestation. This procedure is quite effective, and furthermore it is economically practicable. The stockinet is made in a tubular form suitable for covering the bunches, and its use could be enthusiastically recommended but for one factor, namely its apparent tendency to aggravate thrips infestation. Hence, if stockinet is used to prevent fruit-fly infestation, extra precautions must be taken to keep the thrips population within reasonable bounds. Once a thoroughly effective thrips insecticide is available which will be safe for use by the ordinary banana-grower under average plantation conditions, and it can be applied in conjunction with the covering of the bunches, then the interdependent problems of thrips and fruit-fly control will have been solved.

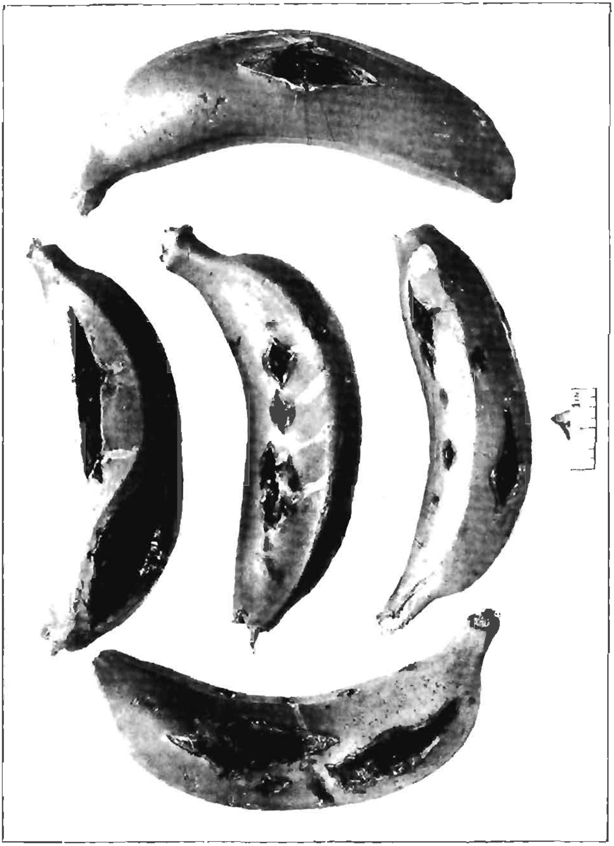


PLATE 32.—DAMAGE CAUSED BY FRUIT-SPOTTING BUGS.

Plate 33.—Damage Caused by Fruit-eating Caterpillars (*Tiracola plagiata* Wlk.).

The Banana Aphis.

The species commonly known as the banana aphis, *Pentalonia nigronervosa* Coq. (Plate 37, fig. 1), occurs practically wherever bananas are grown in this State. Large colonies of this insect may be seen underneath the leaf-bases and in the throat of the plant, and it may be seen in smaller numbers on the fruit and foliage. Furthermore, it may be found in very considerable numbers at the base of the stool beneath ground-level.

This insect feeds by sucking the plant sap, but it is not considered that its presence is of any practical consequence in districts where bunchy top does not exist. Where that disease occurs, it, however, immediately becomes of first-class importance on account of the part it plays as the insect agency whereby the disease is transmitted from an infected plant to a healthy one. Bunchy top is later discussed in some detail in this chapter.

In the early days of the banana industry in Queensland there appears to have been little in the way of disease to trouble the grower. As the industry expanded several maladies came under notice. A few of these, such as bunchy top and leaf spot, may be considered of a somewhat serious nature, while others such as the fruit rots, Panama and dry rot, are for various reasons usually of only minor and local importance. With a view to enabling growers to become familiar with the commoner diseases as they occur in Queensland, there is given in the following pages short descriptions of these, together, where possible, with recommendations for control.

Bunchy Top.

Bunchy top is by far the most serious disease affecting the prosperity of the banana-grower in Queensland. In northern New South Wales and the extreme southern portion of coastal Queensland the once thriving banana-growing industry has, for the time being, been practically wiped out by the ravages of this malady. A similar fate awaits those districts so far free or only lightly affected unless the recommendations designed for the exclusion and control of the disease are strictly adhered to.

The first definite recognition of the presence in Australia of the disease now known as bunchy top occurred in 1913. Apparently it was introduced by means of infected suckers imported from Fiji, where the disease had been prevalent for many years. In 1922 the trouble began to assume such serious proportions as to call for special investigation by the officers of the two States concerned. Finally, in 1924, on the recommendation of a Board representing the Commonwealth Institute of Science and Industry and the Agricultural Departments of New South Wales and Queensland, the Bunchy Top Investigation was appointed consisting of Professor E. J. Goddard (Supervisor), Mr. C. P. J. Magee (Assistant Plant Pathologist), and Mr. H. Collard (Horticulturist). The expenses entailed were met co-operatively by the

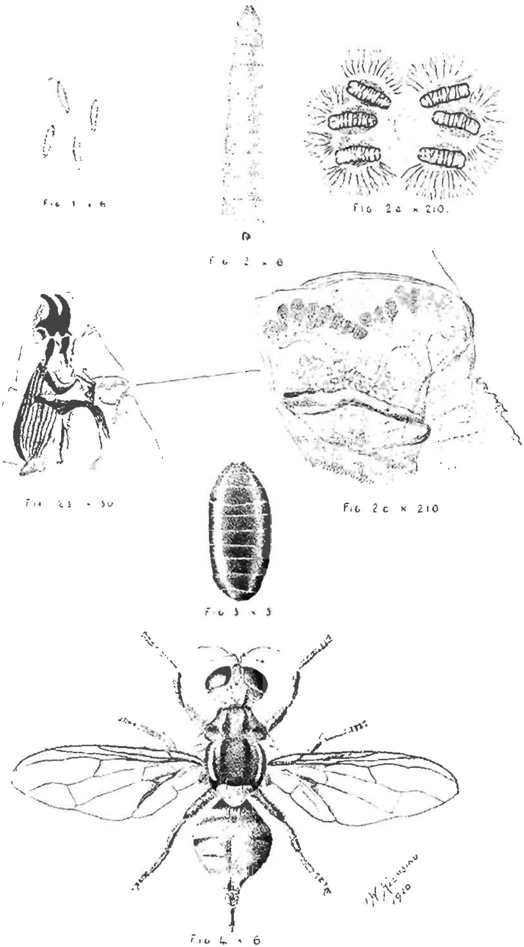


PLATE 31.—THE BANANA FRUIT FLY (*Chaetodacus musae* Tryon).

Fig. 1. Eggs. 6. Fig. 2. Larva. 6. Fig. 2A. Stigmal discs of larva. 10. Fig. 2B. Jaws of larva. 30. Fig. 2C. Anterior spiracle of larva. 210. 3. Puparium, 5. Fig. 4. Imago. 6.

BY TOP.

Commonwealth and the Departments of the States concerned. In Bulletin No. 30 of the Council for Scientific and Industrial Research, Magee has detailed the results of the investigation, and the nature of the disease and its means of transmission are shown to have been clearly demonstrated, with the result that sound control measures may now be advocated.

Symptoms.

The appearance of a typical bunchy top plant showing the later stages of the disease is such as cannot readily be confused with any other banana malady. However, for the purpose of prosecuting efficient control measures it is necessary to be able to detect the first visible symptoms of the disease. These can be searched for by holding the lower part of the youngest leaf of the plant so as to look at it from the back with the light shining through. If the plant has become infected there will be noticed short broken lines of a dark-green colour lying between and parallel to the clear veins which run out at right angles to the midrib. The dark streaks are broken up into short irregular lengths so as to resemble the signs of the Morse code. (Plate 35, fig. 1.) At first the dots and dashes may be somewhat sparsely scattered, but in the later stages of attack these may be so numerous as to form almost continuous dark-green lines, which give to the affected leaf a somewhat darker green appearance than normal. All the leaves subsequently formed exhibit evidence of the disease and to an increasing extent.

The following additional symptoms usually only appear three weeks or more after the marking just described first becomes visible. Suckers infected from the parent, however, may exhibit them from the start and to even greater intensity. Instead of waiting until it is properly free from the pseudostem, the newly thrown leaf will commence unfolding from the top in a funnel-shaped manner. The leaves become reduced in length and width until they are of a somewhat elliptical shape. The blade shows a tendency to droop along the midrib so that the backs of each side approach one another. The edges are rather more wavy than usual and are sometimes slightly curled inwards. Affected leaves exhibit a marked brittleness not natural to the healthy plant. Instead of increasing in size in their order of growth, the leaves of a bunchy top plant gradually become smaller. The leaf-stalk also fails to elongate and bears the leaf in a more erect manner. The result is the formation of a crown of stiff, narrow, erectly growing leaves bunched together in a typically rosetted manner. (Plate 36.) A bunchy top plant affected in its early stages of growth rarely throws a bunch, and when owing to a late infection this does appear it is commonly stunted and possibly malformed owing to the constricted state of the top of the pseudostem through which it has to pass.

Cause.

It has now been demonstrated conclusively that bunchy top belongs to that type of plant malady known as a virus disease. The various plant diseases included in this type show many general points of

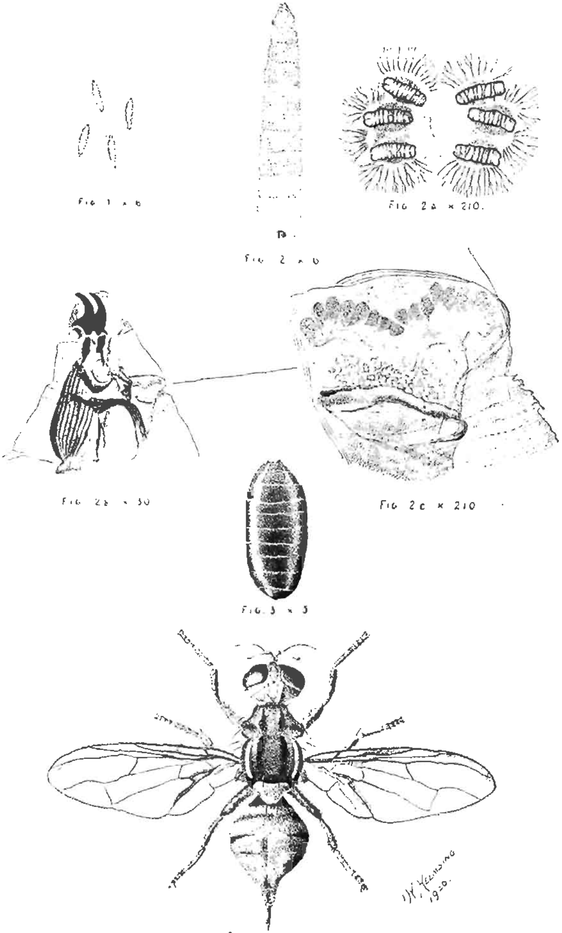


PLATE 34. THE BANANA FRUIT FLY (*Chaetodacus musae* Tryon).

Fig. 1, Eggs, × 6. Fig. 2, Larva, × 6. Fig. 2A, Stigmal discs of larva, × 210. Fig. 2B, Jaws of larva, × 30. Fig. 2C, Anterior spiracle of larva, × 210. Fig. 3, Puparium, × 5. Fig. 4, Imago, × 6.

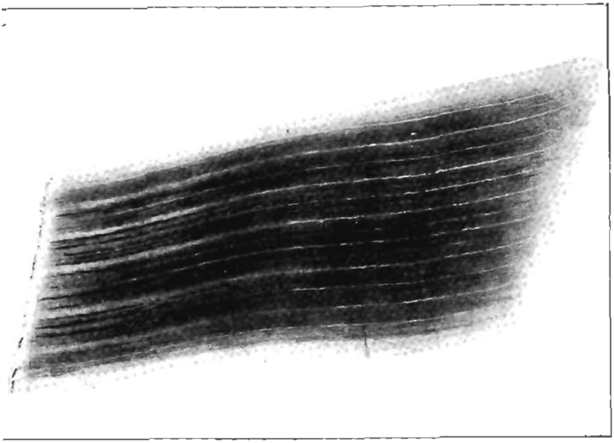


Fig. 1.
A portion from the base of a leaf of a Bunchy Top plant, photographed from the under side by transmitted light, showing the characteristic lines of dots and dashes.

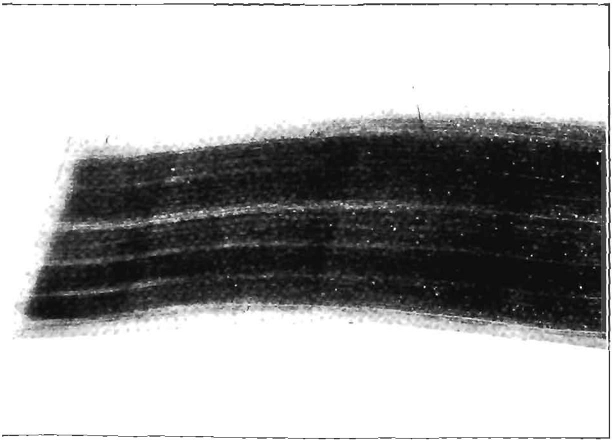


Fig. 2.
A portion of a leaf from a healthy plant photographed in a similar manner to Fig. 1.

PLATE 35.

similarity, of which the chief lies in the fact that the causal agents are of such minute size that they have so far defied all attempts to view them microscopically. What little is known regarding the nature of the infectious agent or virus concerned in the different virus diseases has been determined by experimenting with the plant juice in which it is known to be present. A virus disease may be transmitted from one plant to another in various ways. For some it is merely necessary to inoculate a healthy plant with the expressed juice from a diseased individual. In other cases grafting of diseased on to healthy tissue becomes necessary. In the more specialised forms the virus is conveyed from plant to plant by means of an insect vector. Bunchy top belongs to the latter type.

This disease is disseminated by means of the dark banana aphis (*Pentalonia nigronervosa*) which, in pursuance of its normal feeding habits, may first suck the juice of a diseased plant and then migrate and carry out the same process on a healthy one, with the result that the latter becomes inoculated with the virus and so contracts the disease. (Plate 37.) This insect is responsible for the spread of bunchy-top throughout a plantation and between neighbouring plantations. When one plant contracts the disease the other members of the stool usually become infected as a result of the virus making its way through the connections which link up the various individual corms. Suckers arising from an affected plant almost invariably exhibit symptoms of primary infection from the parent.

CONTROL.

When considering methods for the control of bunchy top it is necessary to stress the following points:—

(1) Bunchy top is a disease of a systemic nature. The causal virus, being present within the living tissue of the host, cannot be destroyed by any chemical or any mechanical treatment known at the present time other than by destruction of the plant itself. In other words, a plant cannot be cured once it has contracted the disease.

(2) Bunchy top may be introduced into a clean area by means of suckers infected with the virus which have been taken from a diseased plantation, and also, if centres of infection are not too far distant, by the possible influx of infected aphis.

(3) The disease is spread within an affected area and also the limits of that area gradually extended by (*a*) the planting of infected suckers; (*b*) the transmission of the virus from diseased to healthy plants by the banana aphis.

(4) An attempt to eliminate bunchy top by complete control of the aphis is beset by so many practical difficulties in the average banana plantation that the method cannot be entertained.

Therefore, since it has not been found possible to either cure a diseased plant or eliminate the means of transmission of the virus, it is necessary to concentrate on a programme of *eradication* whereby all

sources of the infectious agent are completely eliminated by destruction of all diseased plants. With this object in view proclamations have been made which prohibit (1) the transfer of any suckers whatsoever from infected districts into those areas still free from the disease, (2) the removal of suckers from any plantation within an affected area unless the plantation in question has been inspected and found free from the disease.

If this proclamation is adhered to conscientiously by all banana-growers—the very existence of the banana industry in Queensland depends on this—then the following objects will be obtained:—(1) Clean isolated areas will tend to remain clean; (2) spread within affected areas will be greatly reduced.

Growers must not think that these regulations alone are going to eliminate bunchy top. It should hardly be necessary to stress the point that, *owing to the rapidity with which bunchy top may spread*, all growers within an affected area must consider their position as serious. If they do not wish their plantations to follow the fate of those in the Tweed area, the following recommendations must be adhered to:—

(1) Set aside a definite time in every week in which to carry out inspection of the plantation for signs of bunchy top invasion. Each plant should be separately examined, and special attention should be paid to the youngest leaf on each plant in order that the earliest signs of infection may be detected. The area of the plantation should be reduced if necessary to a size which will enable careful examination of this nature to be carried out. Special care should be taken during the warmer months when the aphis are most numerous and active.

(2) If any plant should be found to be infected, the whole stool must be dealt with as follows:—First spray the stool thoroughly with black-leaf 40 to kill all aphis present. Particular attention should be paid to the crevices round leaf-bases, &c. Black-leaf 40 should be used at the rate of a dessertspoonful to a gallon of water, to which soft soap has previously been added until a good lather is obtained. After spraying, dig out the whole stool and cut the plant up into small pieces which will quickly dry out. It must always be borne in mind that it is not sufficient to treat only the individual plant affected, as the virus may have already passed to other members of the stool, although its presence there is not yet apparent.

(3) *All growers should co-operate in seeing that all diseased plants* are eradicated from their district, as it is only by achieving this object that the industry can be expected to again reach a stable basis in the affected areas.

Leaf Spot.

Although some of the oldest growers consider that banana leaf spot has been present in Queensland for the last half-dozen years, it is only recently that the disease has occurred in epidemics of a

PLATE 36 — A BANANA PLANT EXHIBITING TYPICAL SYMPTOMS OF BUNCHY TOP.

Fig. 1A × 210

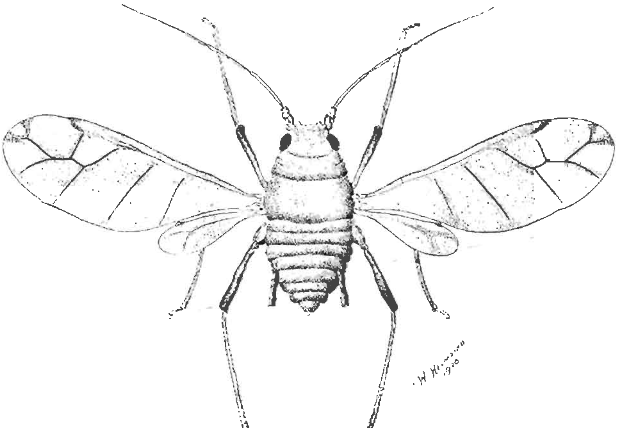


Fig. 1 × 20

Fig. 1B × 210

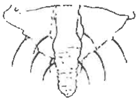


Fig. 1C × 210

PLATE 37.—THE BANANA APHIS (*Pentalonia nigronervosa* COQ.), THE CARRIER OF THE BUNCHY TOP VIRUS.

Fig. 1, Winged adult, × 20. Fig. 1A, Segments 3 and 4 and portion of 5 of antenna of adult, showing sensory organs, × 210. Fig. 1D, Cornicle of adult, × 210. Fig. 1C, Anal segment of adult, × 210.

sufficiently serious nature to cause the grave concern shown in some districts. Leaf spot is now widely spread, and occurs from northern New South Wales in the south to Cairns in the north, including practically the whole of the area in which banana-growing is practised.

SYMPTOMS.

The first indication that a leaf has become infected is the appearance of indistinct linear markings of a light brownish-green colour. These areas are ⅛ to ⅜ inch in length and lie parallel to the direction of the veins, two to four of which may be included in their width. These *initial spots increase somewhat in width and length and dry out slightly*, becoming dark muddy brown to black, linear, linear oblong, or elliptic areas of ¼ to ½ inch in length and about one-third or less of this in width. (Plate 38.) On the lower leaves of young plants the spots are larger and broader and show as dark-brown oval to almost eircular areas up to ½ inch in diameter. (Plate 38A.) The spots early become surrounded by a diffuse light-green halo, which soon turns a dark yellow and extends its area into the surrounding leaf surface, more especially towards the margin. The central portion of the dark spot representing the region first to be invaded usually dries out to form a lighter grey area, which is often speckled with the black fruiting bodies of the fungus causing the disease. These grey linear or elliptical areas, bordered with black and surrounded with a yellow halo, are characteristic of the disease. Usually the grey spots can be easily distinguished even after the leaf has completely withered. (Plate 38C.)

The part of the leaf exhibiting yellow discolouration gradually turns brown and dries out. When the spots are sufficiently numerous several lesions may coalesce, so that there are formed large peninsulas of dead *and dying tissue extending from the margin in towards the midrib and* including further spots as these extend. Finally the whole leaf will shrivel.

In a bad attack the spotting will pass from the lower leaves in succession up the plant until all the leaves are left dead and hanging drooped round the rotting pseudostem. The quality of the fruit is reduced by the loss of leaves. When defoliation is severe the bunch will vary in its development according to the stage of maturity at which the loss of leaves occurred. If this should take place before the fruit have filled out, the bunch will frequently fail to mature sufficiently to be fit for market. This is specially the case with bunches which normally would be cut during the winter and early spring months.

CAUSE.

Banana leaf spot is caused by a fungus belonging to the genus *Cercospora*. The spores of this fungus are narrow elongate, many septate structures formed on the ends of dusky brown upright fungal stalks or hyphæ which project in clusters from the surface of the brown or grey areas mentioned above.

Spore formation may commence soon after the lesion has assumed the dark-brown stage, but the presence of the spore clusters is not easily detected until the central spore-bearing region dries out, when they give rise to a speckled appearance over the lighter area so formed. Spores may be found on both sides of the leaf, but as a rule by far the greatest number are produced on the upper surface. From the diseased areas they are scattered by wind and rain to healthy leaves, where, if weather conditions are suitable, they germinate and produce further spotting. On an individual plant the leaves become infected in the order of their maturity from the oldest upwards, and in many cases there is definite indication of infection from a spotted leaf below.

Varietal Susceptibility.

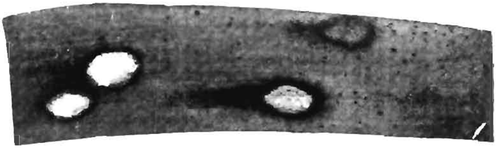
The Sugar and Lady's Finger varieties appear to be somewhat less affected by this disease than the Cavendish, possibly in part owing to their more open habit of growth.

Seasonal Nature of the Disease.

Leaf spot is of purely seasonal occurrence. The first noticeable appearance is usually about the beginning of March, and from then on the disease becomes increasingly prevalent until the end of winter. With the advent of spring-growing conditions, the disease quickly disappears, the new leaves coming away free from infection. It is usually possible to find some lesions throughout the year, but during the early summer months these are not abundant except associated with old trash. Preliminary experiments with the *Cercospora* responsible for leaf spot have indicated that both vegetative growth and spore development are retarded by temperatures above 80 deg. Fahr. The fact that during the summer months in Queensland the temperature commonly ranges above this point may explain to a certain extent the absence of leaf spot during this period. However, the marked slackening in growth of the banana plant as well as other conditions mentioned below, are considered to largely contribute to the severity of outbreaks during the cooler months.

Contributing Conditions.

It has not been possible so far to accumulate data regarding the direct relationship between weather conditions and the severity of leaf-spot occurrence. Mr. S. E. Stephens, Inspector, Diseases in Plants Acts, has recorded for the Innisfail district a marked increase in the disease following cold snaps. An abnormally wet rainy season in January and February appears to allow an earlier development of the disease. Possibly the root rot, which in many cases accompanies these conditions, contributes to the severity of the attack by weakening the plant. Large plants growing under ideal conditions of soil and location may not be affected to the serious extent displayed by those in poorer, badly drained plantations.



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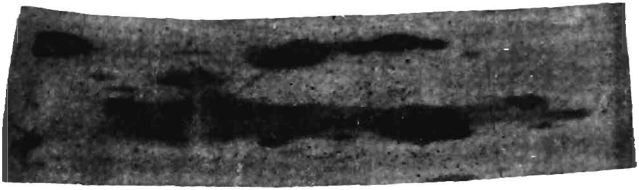

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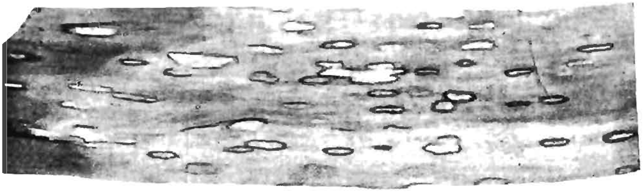


C.

PLATE 38.—BANANA LEAF SPOT.

A, Spots as they appear on the first formed leaves. B, Leaf tissue commencing to die as a esult of Leaf Spot attack. C, Spots showing up conspicuously on dry leaf killed by the disease.

Severe individual attacks of leaf spot are frequently associated with the presence of beetle borer, and it is possible that the increase in severity of the disease as a plantation ages is in some measure due to the increase of the insect pest.

Apparently a state of lowered vitality brought about by cool weather or other causes is conducive to severe attack. During periods of rapid growth new leaf development keeps pace with the spread of the disease. Infection of all the foliage seldom takes place before the plant has bunched and leaf production ceased. Even then the abundant spotting leading to complete defoliation seldom occurs until the fruit is approaching maturity and no doubt making use of all available food energy.

CONTROL.

Although leaf spot has probably been in Queensland for the last half-dozen years, if not longer, the disease has only recently assumed epidemic form of sufficiently serious nature to attract attention. It is, therefore, not possible at the present time to recommend any certain means of control. Spraying or dusting with a fungicide, which might be advocated for this type of disease, becomes unsatisfactory from the practical standpoint when dealing with a plant such as the banana. However, an experiment to test the efficacy of dusting was carried out during the past epidemic through the much appreciated co-operation of one grower, but the results in this case were not such as would justify the advocation of this method of control. The value of systematic stripping as a means of reducing the severity of an attack is also being tested out on several plantations. The results from this experiment are not yet available.

The following suggestions for the control of leaf spot are provisionally submitted:—

(1) Care should be exercised when selecting a site for a plantation to see that the aspect, soil, and other conditions are those best suited to the vigorous growth of the bananas throughout the year. Good cultivation, and, if possible, manuring should also be practised with the same object in view.

(2) Suckers should be planted as far apart as is economically possible, in order to reduce the damp conditions arising in a plantation and lessen the rapid spread of the disease from plant to plant.

(3) The disease appears always to start on the lower leaves. The spores produced on these in enormous numbers are blown or splashed on to healthy ones above, and these germinate and produce further centres of infection. By carefully removing, by means of a series of frequent inspections throughout the year, all leaves or portions of leaf showing the spots, it should be possible to so reduce the amount of infectious spore material present in the plantation as to make it possible to tide the plants over their susceptible period without extensive damage being effected. The leaves on removal should be burnt or buried below risk of disturbance. The leaves should be removed when the spots

are in the light-brown stage, as spore formation may commence soon after they have darkened, and the dispersal of these may nullify the results desired. Special attention would have to be paid to these sanitary measures during the first half of the year when the fungus is on the increase, and the grower might well allocate certain days, at not longer than fortnightly intervals, on which the inspection and destruction would take place. For most efficient treatment with least effect on the plant, stripping should be commenced on the first appearance of the disease. Treating a plantation already heavily infected may not yield appreciable control, while the excessive stripping then necessitated may tend to weaken the plant. The fact that the amount of leaf spot appearing in a new plantation is slight, and increases only as the stools age and more spore-bearing material accumulates, would indicate that this method of control is well worth a thorough trial.

Leaf spot usually first appears in a new plantation as more or less isolated spots on the lower leaf or two of the young plants. Probably these are derived in many cases from spores introduced with the suckers on to which they had fallen in the old plantation. Careful attention given to the removal of these first affected leaves, as soon as the spots appear, may be of special help in reducing the rate of subsequent spread of the disease.

Panama Disease.

This disease affects only the tall-growing varieties of banana, including the Lady's Finger, Sugar, and Gros Michel. The Cavendish or dwarf banana appears to be completely resistant under Queensland conditions, and since this is the common commercial variety grown in Queensland, Panama disease has not so far become the serious menace in this State that it has in other banana-growing countries where the Gros Michel is the standard. Very considerable loss has been sustained, however, by those cultivating susceptible varieties, more especially since few of these growers realise that they are dealing with a specific disease, so that methods of exclusion and eradication are seldom practised.

Symptoms.

The first signs of an attack of Panama appear on the lower leaves of the plant. The leaf-blade commences to turn a deep-yellow colour round the margin and along the edges of any shredded segments. As the yellowing advances inwards the portion first affected turns brown and dries out. After this has progressed to a certain extent, the leaf-stalk collapses near its junction with the sheathing base, and the dying leaf hangs down round the pseudostem. The leaves are progressively affected in this manner from the base up, and finally the pseudostem may appear devoid of all green leaves with the dry shredded remains of these hanging round it. Frequently the outer sheathing bases of the leaves will split upwards longitudinally.

If the plant is infected in the early stages of its growth a bunch may not be thrown or, if one is produced, this will be stunted and the fruit will not mature properly. Plants less seriously affected will

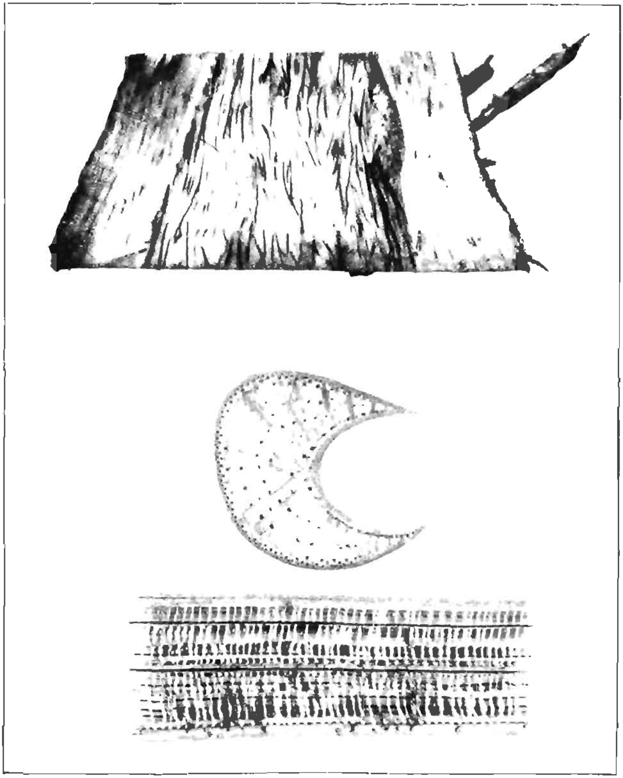


PLATE 39.—PANAMA DISEASE.

Above.—Longitudinal Section of affected corm, exhibiting characteristic blackening of the vascular strands.

Below.—Transverse and longitudinal sections of a leaf-stalk, showing the continuance of the discoloured strands into this region.

often throw a marketable bunch, but one inferior to that which would have been produced by the plant in a healthy state. This latter state may occur in the case of the Lady's Finger variety, which appears to be somewhat more resistant to the attack of Panama.

The best diagnostic characters of Panama disease are internal. If the butt of an affected plant be dug up and split lengthwise, the base of the corm will be found to be discoloured by numerous reddish-brown to black lines running in all directions through the white tissue, and sometimes so numerous as to cause almost complete blackening of the central region of the corm. These lines represent the vascular strands composed of large water-conducting cells which are here rendered conspicuous by the discolouration brought about by the presence of the fungus or its toxic secretions within them. The brown vessels can be followed up through the corm into the sheathing leaf bases, and from there will often be found extending almost to the ends of the midrib of the leaf. (Plate 39.) A quick diagnosis for Panama can often be made by slitting up the base of the stalk of a withered leaf, near its junction with the pseudostem, when these affected vessels may be observed as one or more light yellowish-brown, brown, or reddish-brown lines running up the vertical partitions of the stalk.

Cause.

Panama disease in Queensland would appear to be caused by the same fungus (*Fusarium cubense*) as is responsible for the disease in Central America. The fruiting bodies of this fungus are produced on both upper and lower surfaces of the leaf and leaf-stalk. They take the form of minute clusters of branched fungus threads which project through the epidermis and bear numerous small sickle-shaped spores. The spores are washed away by the rain and blown by the wind, and if in the process they reach a suitable situation they may germinate and infect a healthy plant.

The spores are capable of developing and growing for a certain time in the soil. Infection may take place through young tender roots or through wounds in the corm. Once within the plant the fungus grows up through the vessels, producing the symptoms noted above. Infection of young plants frequently takes place by the fungus present in an old parent corm growing out through the tissue connecting it to the surrounding suckers, and in these setting up the same diseased conditions as obtained in the parent. The planting of such infected suckers is one of the chief means of distributing the disease.

Control.

The only satisfactory way of dealing with Panama disease is by a combination of exclusion and eradication.

(1) Only land which has not previously grown bananas, or land on which Panama disease has never been known to exist, should be

planted with susceptible varieties. This precaution is necessary since the fungus may remain for a number of years in the soil even after affected plants have been removed.

(2) Special care should be taken that suckers are obtained only from a district in which Panama disease is definitely known not to exist. Suckers obtained from within an infested area are always liable to be infected, and signs of this might escape detection by the grower.

(3) In spite of these precautions a plantation may become infected by means of wind-borne spores or by infectious material accidentally introduced on boots, &c. A careful watch should therefore be kept for the appearance of the disease, and, if a plant is observed showing symptoms of Panama, the whole stool should immediately be dug out and the affected plant, together with any invaded suckers, should then be removed carefully so as to avoid spreading spores about, chopped into pieces and burnt. Any instrument used in cutting a diseased plant must be disinfected by washing in a fungicidal solution, or by passing through a flame, before it is again used on a healthy banana. It is important for this eradication process that diseased plants are detected and removed in the early stages of the disease before spore formation has commenced. It is very unwise to replant in the spot from which a stool has had to be removed.

Dry Rot.

Dry rot is not a disease of serious consequence, owing to the fact that it is only an isolated plant or a small group of plants that is usually affected. However, in the absence of knowledge regarding the disease, its appearance sometimes causes concern.

Symptoms.

An individual plant or stool may exhibit a cessation of vigorous growth and later the leaves commence to die back from the margins. Finally the whole plant dies back and turns brown and dry.

It will be found that the plant so affected may be easily pushed over as it is practically devoid of sound roots. On cutting open the corm a portion or the whole of the interior is seen to have been changed to a substance of a more or less dry, "punky" nature of a dirty white to brown colour. This consists of a mass of closely interwoven fungal threads which have invaded the corm and largely replaced the plant tissue.

Cause.

Dry rot may be caused by several fungi, including a *Poria*, belonging to the Basidiomycetes or higher fungi. These fungi live for the most part on dead and rotting stumps, such as are usually present in abundance in the average banana plantation. From here certain of them are able to pass to a living banana plant, should such be growing

in close proximity, and, by invasion of the corm, produce the dry rot described above. Growers have noticed that the stumps of certain species of trees are more commonly associated with these dry-rot-producing fungi.

Control.

Often dry rot does not spread beyond the original stool attacked, but in some cases the fungus gradually extends its area of attack to adjacent stools. For this reason it is advisable, when a plant is observed to be affected, to locate, if possible, the stump or root from which infection has proceeded and remove and burn this together with the affected corm.

Fruit Rots.

A.—STEM-END ROT.

This disease is sometimes known as black end, owing to the fact that affected fruit exhibit a black area of soft rot round the stem end.

Symptoms.

The trouble usually commences as a dark water-soaked area formed in connection with a bruise or other injury to the short fruit-stalk or working in from its broken end. (Plate 40, fig. 2.) As the rot progresses the stalk turns completely black and becomes much shrunken and sometimes shredded. From the stalk the soft blackened area extends through the skin of the fruit at a more or less rapid rate, the pulp beneath turning soft and watery.

Stem-end rot is not a disease of the plantation, as it usually appears only when the fruit are approaching maturity, especially after long-distance consignment.

Cause.

Associated with this rot are usually to be found fungi of the genera *Verticillium*, *Glœosporium*, and *Fusarium*. It would appear that under suitable conditions any weak wound parasite of this type would be capable of producing similar injury. Careful examination of affected fruit will reveal the fact that the primary cause of the trouble lies in injuries *given to the fruit during the frequent handling to which it is subject. The injury may be due to bending the fruit-stalks* while the hand is still on the bunch. The bruise resulting from this is sufficient to constitute a point of entry for the rot-producing fungi without a definite abrasion *of the skin*. The wounds and bruises arising from tearing apart the fingers from the hand will also serve as infection points. These latter are a common source of trouble in cased fruit.

Control.

(1) As regards fruit marked in the bunch, it is essential that the bunches receive most careful handling from the time they are cut until they reach the consumer. When one considers the rough treatment the fruit is often subjected to it is remarkable that not more damage results.

(2) In order to lessen stem-end rot in cased fruit it will be necessary to pack in hands or half-hands rather than in singles. The hands should be carefully cut off round the collar by which they are attached to the central stalk, and if it is necessary to reduce them in size the division should be made by a sharp knife and not by a tearing process.

(3) The grower should avoid accumulating a heap of rotting banana refuse round his packing shed. This material serves as a breeding ground for the various organisms causing stem-end rot, and spores produced here may serve to contaminate fruit during the process of packing. The discarded fruit and stalks could be thrown into a pit and covered every now and then with a layer of soil.

(4) The same need for cleanliness may be stressed with regard to some ripening rooms. The absence of a regular cleansing programme will increase the chance of infection with rot fungi.

B.—ANTHRACNOSE.

Anthracnose is of rare occurrence in the plantation, where it occasionally appears in the form of a leaf and fruit spot. More commonly it is met with as a ripe rot of the fruit on the market.

Symptoms.

The early stages appear on the skin of a ripening fruit as small muddy brown rather diffuse spots. These enlarge rapidly and take the form of slightly depressed areas, rounded or irregular in shape, and dark brown to almost black in colour. The spots may coalesce until large areas of surface present a black, rotting appearance. When subjected to moist conditions, the older parts of the affected areas become covered with minute pink pustules formed by the spore masses of the causal fungus. (Plate 40, fig. 3.) In the early stages the affected area is restricted to the skin, but soon the pulp below the spot becomes invaded and takes on the water-soaked appearance of a soft rot, which rapidly spreads through the tissue rendering the fruit unfit for consumption.

Anthracnose occasionally appears on the leaves as large elliptical brown areas which may extend to include considerable areas of leaf surface.

Cause.

Anthracnose is caused by a fungus (*Gloeosporium musarum*). This organism is only of a weakly parasitic nature and is not usually found attacking fruit except in the later stages of ripening. It may considerably hasten what is commonly termed the over-ripe condition. Bruising of the fruit will contribute to the attack of this fungus.

Control.

The control measures for anthracnose should follow the same general lines as advocated for stem-end rot. Attention must be paid to careful handling to avoid bruising, and to the practice of cleanliness at the packing shed, market, and ripening room.

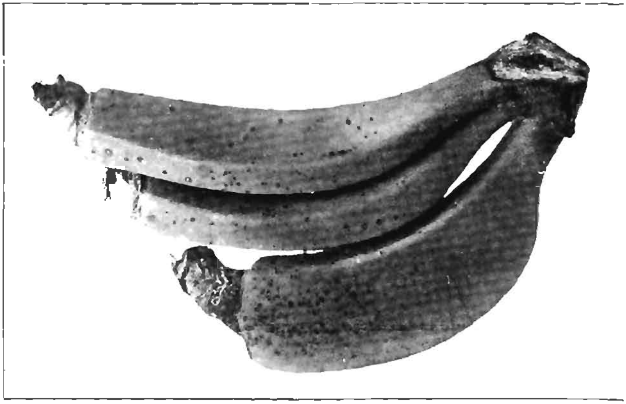


Fig. 1.—Cigar End.

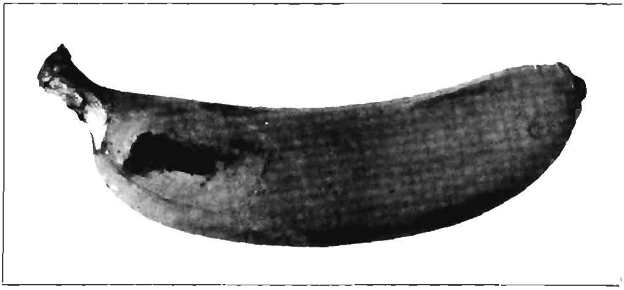


Fig. 2.—Stem End Rot.

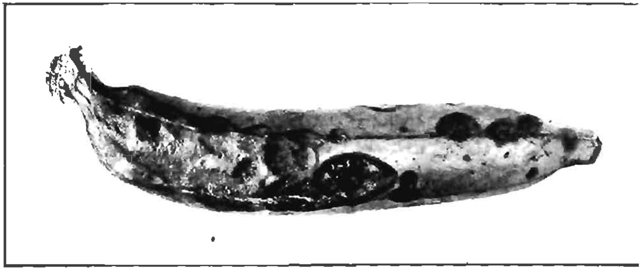


Fig. 3.—Anthracnose.

PLATE 40.

C.—CIGAR END.

In contrast to the two previously mentioned fruit troubles, cigar end is a disease to which the fruit become subject in their more immature stages. Commonly only a few of the fingers on a bunch exhibit the symptoms, but records have been received in which the whole bunch has been affected.

SYMPTOMS.

Affected fruit exhibit a firm black rot at the apex. The extent of the decay varies from a scarcely noticeable ring of black tissue round the terminal crown to a regular extension back for half an inch or more. The affected portion shrinks, in many cases becoming more or less rounded in contrast to the angular shape of the immature fruit. (Plate 40, fig. 1.) The blackened tissue then becomes covered from distal end back with an ashy grey or sometimes pinkish grey coat of fungal spores, which give, in typical cases, the striking resemblance to a burnt cigar-tip to which the disease owes its name. The old shrivelled floral organs often persist for considerably longer than the normal period on affected fruit.

CAUSE.

A fungus (*Verticillium sp.*) is almost universally associated with cigar end, and it is the conidiophores and spores of this organism closely studded over the affected region which give rise to the grey covering characteristic of the disease. A consideration of the early stages of attack would suggest that infection may possibly take place through the tender floral structures, which appear particularly susceptible to fungus invasion.

CONTROL.

Definite recommendations based on a full investigation cannot be made at present. It is suggested that the young bunch be opened up to the light and air, and the bracts which sometimes tend to remain attached to the developing hand, especially during wet weather, be removed as soon as possible.

D.—SQUIRTER.

Squirter is a trouble of a somewhat obscure nature which shows up mainly in connection with fruit which has undergone long-distance consignment to Southern States. After ripening, the centre of the fruit will be found to have turned to a soft, watery mass, which will squirt out when pressed. The symptoms would suggest that squirter may be connected with physiological disturbances arising out of the present ripening and transport methods. The true nature and cause of squirter is at present under investigation.

CHAPTER X.

PESTS AND DISEASES OF PINEAPPLES.

The contents of this chapter will of necessity deal mainly with pathological matters, for, with the exception of nematode infestation, there is comparatively little associated with the pineapple plant that concerns the entomologist. Nematode infestation is quite abundant in this State and it constitutes a decidedly important problem; this widespread and destructive pest is, however, dealt with in considerable detail in Chapter XIII., and growers who are troubled by it in their pineapple plantations are accordingly referred to that chapter for information with respect to its life history and control.

White grubs, which are the larvæ of various species of beetles belonging to the *Scarabæidæ*, are sometimes of importance to pineapple growers on account of their habit of feeding on the root system of a large number of plants, included amongst which is the pineapple. In Northern Queensland several species of white grubs are major pests of sugar-cane, and they have been the subject of very detailed investigation by Edmund Jarvis, Illingworth, Girault, and other officers of the Bureau of Sugar Experiment Stations associated with the Department of Agriculture and Stock. Arising out of that investigation, certain measures have been recommended for the control of sugar-cane grubs, included in which is the use of paradichlorobenzene as a soil fumigant. Paradichlorobenzene may be equally effective in dealing with the white grubs that are destructive to pineapple crops. The safe and effective dosages would, however, have to be tested out experimentally in the field before definite recommendations could be made in favour of its use against white grubs attacking pineapples.

Mealy-bug infestation sometimes occurs in pineapples, but further investigation will be necessary before the control of these insects can be discussed. At present they certainly cannot be regarded as pests of major importance.

Fruitlet core rot, which was investigated by Tryon many years ago, was associated by him with the presence of a mite, so that the disease in question has certain entomological aspects. It is discussed in some detail in the subsequent pages of this chapter.

The pathological problems to which reference will now be made are the following:—Wilt, base rot, Thielaviopsis fruit rot, fruitlet core rot, top rot, and tangle root. Before discussing these problems a brief reference must, however, be made to certain features in the growth habits of the pineapple.

The pineapple belongs to a family of plants many of whose members live on trees and rocks, where they have become adapted to more or less of an air-dwelling habit. Although itself a soil-inhabiting species,

the pineapple resembles these plants to a certain extent in structural features, and possibly as a correlated character exhibits a marked intolerance of conditions leading to bad soil aeration.

The pineapple is also a heavy feeder, and judicious fertilising is necessary on any but good soils. Poor drainage and lack of the necessary soil nutriments constitute the primary cause for much of the so-called disease met with in Queensland. There are, however, several specific diseases of a parasitic nature which will be found included below.

Wilt.

The presence of pineapple wilt in a field is indicated by the appearance of certain areas in which the plants exhibit a general unthrifty condition, together with a stunting of the plants and any fruit which may be produced. The leaves assume a reddish-yellow colouration in marked contrast to the normal healthy green. They commence to turn brown and dry out from the tip, giving rise to the appearance suggesting the common name of wilt. Examination of the affected plants will show that, corresponding to the outward manifestations of disease, the root system will present various stages of decay. Even before external symptoms become visible the younger rootlets may be found to have perished.

Cause.

This disease was investigated and reported on by Tryon as early as 1893. A further full account of these researches was published in the "Queensland Agricultural Journal," vol. xv., 1904. Tryon found that there was a definite fungus associated with the decay of the roots. This organism, however, was unable to infect plants unless they were previously subjected to some unfavourable growing conditions which impaired their vitality. He was able to show, by extensive field observations and by the elimination of other possible factors, that the contributing condition was to be found in the nature of the soil and its drainage. Wilt makes its appearance when the crop is grown on soil of shallow depth with a stiff subsoil. The pineapple is a plant which is able to grow well under quite moist conditions, provided drainage is adequate, but it is unable to resist the ill-effects of standing water.

From a consideration of the past history of the disease it was shown that a contributing cause was the occurrence of periods of unusually cold weather at the time when the plants were subjected to heavy rainfall.

Control.

In order to avoid having trouble of this nature, growers should not plant on shallow, poorly drained land. If for any reason such land has to be used, a system of artificial drainage will be found beneficial.

On poor land "wilt" symptoms may also arise as the result of some deficiency in plant food. The remedy for this would naturally lie in improving the growing conditions by judicious manuring.

Base Rot.

There are two characteristic diseases induced in the pineapple by the fungus *Thielaviopsis paradoxa.* One is the decay of the stem known as base rot, the other is a soft rot of the fruit which will be dealt with subsequently.

Symptoms.

Pineapple suckers sometimes fail to develop normally after planting out. Such plants remain more or less at a standstill and cease to produce new growth. Later a yellowing and withering of the leaves commences and the sucker eventually dies. The plants exhibiting these symptoms will be found to be loose in the ground, and closer examination will disclose a black area of rot invading the base of the stem. (Plate 41, fig 1.) The rot gradually extends until the whole of the lower part of the sucker, together with some of the lower leaf-bases, may be involved. The plant is then liable to break off at ground-level.

Older plants are sometimes affected with this trouble, the symptoms being very similar to those described above.

A loss of as many as 80 per cent. of the suckers from one planting has been reported during a wet season. The average is, however, considerably less than this.

Cause.

This rot is caused by a fungus (*Thielaviopsis paradoxa*) which may infect the plant through wounds, or under favourable conditions even through the uninjured surface. Within the invaded area there is set up a soft rot which is at first brown but later changes to an almost sooty black colour owing to the development, from the fungal threads or mycelium within the tissue, of very numerous dark-brown oval spores. These spores are liberated by the complete decay of the affected part and then serve to further spread the disease.

Control.

1. After pulling, and if necessary stripping the suckers ready for planting, dry in the sun for a few days.

2. Avoid planting during very wet weather.

3. As a further precaution the stripped suckers may be dipped in strong Bordeaux mixture before drying. Dipping alone cannot be relied on to give satisfactory control.

4. All diseased suckers, &c., should be removed and burnt. Otherwise the spores of which the rotting tissue is full will be liberated into the soil, where they will be available to produce further infection in new plants.

Thielaviopsis Fruit Rot.

The same fungus (*Thielaviopsis paradoxa*) as that implicated in base rot is the cause of a rot of the ripening fruit, especially when this has become bruised or otherwise injured by rough handling. On the

Fig. 1.—Base Rot of Pineapple Suckers.

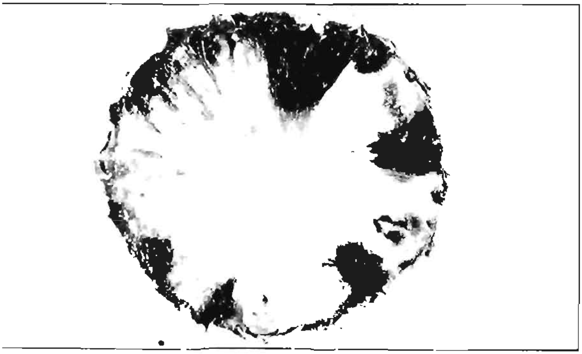


Fig 2.—Fruitlet Core Rot

Plate 41.

fruit the rot will be indicated externally by the presence of a dark somewhat sunken area on the skin. Internally the affected region is at first watery and yellow, but later turns black as the macrospores of the fungus commence to be developed.

Occasionally the leaf of the pineapple is attacked, giving rise to light-yellow or straw-coloured spots of fairly regular outline surrounded by a narrow brown margin. These spots are usually developed in connection with scratches caused by the spines of contiguous leaves. While not in sufficient numbers to have any deleterious effect on the plant, these lesions may serve as one means for the perpetuation of the fungus in the field.

To avoid Thielaviopsis fruit rot care must be given to handling and packing in order to avoid any injury which might aid the fungus in its attack. The farm must be kept free from rotting fruit and other pineapple refuse, as this may cause the accumulation of the fungus spores, which will contaminate the air in which marketable fruit has to lie.

Fruitlet Core Rot.

This disease is one found more commonly in connection with the winter crop of pines at a time when loss can be ill afforded on account of the high prices then obtainable.

Symptoms.

The first symptoms may appear as the fruit approaches maturity, in the form of a failure of an isolated fruitlet or group of fruitlets to mature in conformity with the rest of the fruit. The affected portion retains a greenish colour while the rest is undergoing the normal yellowing. In other cases an affected fruit may exhibit no apparent external symptoms of the decay which may be present within. On cutting through one of these affected fruitlets there will be found a more or less extensive area of brown decay extending inwards from the base of the floral chamber. (Plate 41, fig. 2.) The extent to which the rot will extend depends on the number of fruitlets affected in the first place, and the conditions to which the fruit has been subjected favouring spread through the tissue. In some cases a considerable portion of the fruit may be involved, while in others there is little interference with the edible qualities.

Cause.

Fruitlet core rot was first investigated in Queensland by Tryon in 1898, and the results of his work published in the "Agricultural Journal" of that year. He considered a mite (*Tarsonemus ananas* Tryon) to be the primary cause of the trouble so far as the Ripley Queen variety of pines was concerned. This mite is found in the cavity enclosed by the fleshy floral organs of the fruitlets, and in pursuance of its feeding habits pierces the softer tissue at the base of this floral chamber. A fungus (*?Monilia sp.*) which commonly occurs in the cavity is able to extend by means of these injuries and set up the rotting condition characteristic of

the disease. The same author considered a similar disease affecting the smooth-leaf pine to be of a somewhat different character, since the fungus associated with it belonged to the genus *Penicillium*. Lately isolations made in separate instances from Ripley pines have yielded a *Penicillium* and a *Fusarium* apparently unassociated with other organisms, suggesting their possible causal relation to the rot.

Control.

Before definite control measures can be recommended, further research will have to be undertaken into the general biology of the pineapple flower and the various fungi associated with rots of this type, giving special attention to their mode of transmission, infection, &c.

It has been noted that the extent of rotting is aggravated by tight packing, and care in this respect may help to alleviate the damage caused by this disease.

Top Rot.

Top rot is a disease which is rather sporadic in its distribution and for this reason may be unknown to many. It is only recently that this trouble has received attention, and many points have to be cleared up before definite control measures can be advocated. However, since a number of growers are concerned regarding this disease, a short note dealing with it is included here.

Symptoms.

The general appearance of a plant affected with top rot is not unlike the condition commonly known as "wilt." There is usually a certain amount of stunting and yellowing of the plant as a whole, and the leaves, especially the younger more upstanding ones, die back and shrivel from their tips. Finally the leaves fall flat and the plant breaks off about ground-level, when the upper portion of the stem will be found to be completely rotten. In the early stages of the disease, in order to determine whether top rot, rather than other causes of "wilt" symptoms, is present, it is necessary to attempt to pull out the terminal crown of leaves. If the plant is affected this will come away easily, and the leaves will be found to exhibit a light or somewhat mud-coloured rot at their base.

Infection appears to commence at the top of the stem. A longitudinal section of an affected plant will show an area of rotting tissue, flat-white in colour, near the apex. This may be of a fairly firm nature, but commonly invasion of soft-rot organisms produces a foul-smelling soft rot. (Plate 42.) The rot extends through the stem, working up through the leaf-bases as these are reached. The leaves are not usually invaded for more than half an inch up except towards the top of the stem, where more may be included and even the whole of the young terminal shoot affected. The advancing edge of rot in the leaves is defined by a somewhat irregular water-soaked band, while in the stem and older leaf-bases there

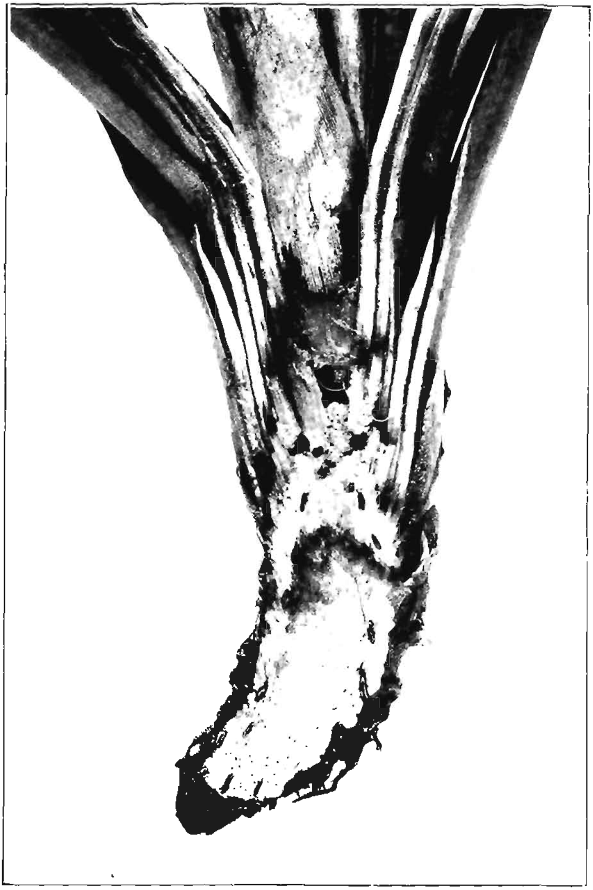


PLATE 42.—LONGITUDINAL SECTION OF PINEAPPLE AFFECTED WITH TOP ROT.

is a definite dark-brown border. Top rot may affect scattered plants, but it is more common to find certain areas of the plantation exhibiting a fairly high percentage of infection while the rest is practically free. A loss of from 60 to 70 per cent. has been noted in such places. This localisation does not appear to be dependent on special soil factors.

The disease may be found affecting all the common commercial varieties of pineapple, though possibly the Ripley variety has shown the highest infection. Plants grown with and without paper mulch may be attacked. Loss from top rot occurs in new plantings before the first fruit are thrown; older plants appear to be rarely attacked.

Top rot makes its appearance about the middle of winter, and from then onwards until early summer plants may be found showing the disease in various stages. Apparently the disease reaches serious proportions only after seasons when the summer and autumn rains have been exceptionally heavy.

CONTROL.

A fungus (*Phytophthora sp.*) has been isolated in several instances from the margin of invasion into young leaves. Although it is considered possible that this organism is causally related to the disease, a definite conclusion will have to await the results of inoculating this fungus into healthy pines. In the meantime it may be assumed that the disease is of a parasitic nature. There is also evidence that spread of the disease takes place by means of spores formed in connection with the decaying leaf-bases. The water lodging round the bases of the leaves forms an excellent situation in which spore production and also infection may take place.

It is therefore recommended that affected plants be carefully removed and burnt as soon as they are detected; in this way spread of the disease may be considerably checked. Some growers have been in the habit of leaving the old butt in the ground, since a shoot will often appear from below the rotted region and a healthy plant result. This is unwise, as the remains of the previously rotted portion may serve to spread the disease to other plants later.

Tangle Root.

Tangle root is not a disease of a parasitic nature, but is due to a combination of certain unfavourable meteorological and soil conditions.

SYMPTOMS.

Tangle root appears usually in a newly planted field. Certain of the young plants fail to keep pace with their companions, and commence to assume a reddish-yellow colouration of the leaves, which gradually die back from the tips. The number of affected plants varies considerably, and these are usually scattered indiscriminately along the rows.

Cause.

The aboveground symptoms somewhat resemble wilt, but on pulling up a plant the difference will become apparent. It will be found that the roots, in place of radiating evenly from the base of the sucker, are wound tightly round the stem beneath the persistent leaf-bases. (Plate 43.) The roots in this condition are unable to perform their normal function of nourishing and sustaining the growth of the plant.

The trouble arises from planting suckers during dry weather in badly worked or stiff soil. Under these conditions the lower leaves do not rot off, and the roots developing from dormant buds lying beneath them are forced to circumnavigate the stem in their efforts to find a way out of the soil. Daughter suckers on older plants may sometimes exhibit the same trouble and fail to root, when, as is usually the case, they bend over to the ground, thus leaving the fruit less well nourished.

Control.

1. Tangle root may be easily prevented by stripping off a few of the lower leaves of the suckers, which should then be dried for a few days in the sun in order to lessen the chance of subsequent rotting by *Thielaviopsis*.

2. Plant only in well-worked land that is not in an excessively dry condition. See that good cultivation is afterwards maintained.

Other Pineapple Diseases.

Certain other diseases of the pineapple, such as black heart and water blister, are more or less of seasonal occurrence, and are possibly of physiological rather than parasitic origin. Little is known regarding these maladies, and investigation of these and other pineapple diseases is being prosecuted as opportunity permits.

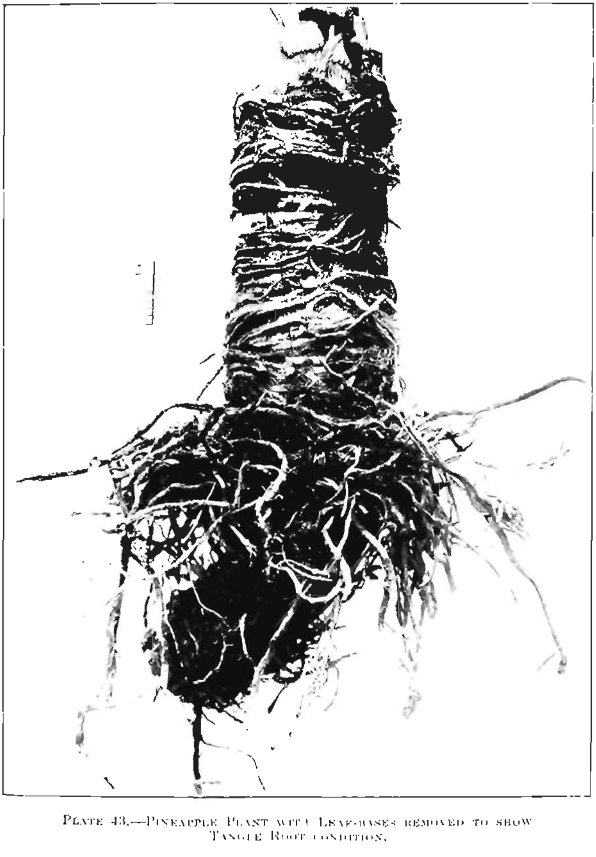


Plate 43.—Pineapple Plant with Leaf-bases removed to show Tangle Root condition.

CHAPTER XI.

PESTS AND DISEASES OF TOMATOES.

Entomologically the position with respect to tomatoes is far more acute than in the case of the crop dealt with in the preceding chapter, namely pineapples. Tomatoes are also subject to many fungus and other diseases which are frequently responsible for very serious losses.

Shortly after the seedlings appear above ground they may be attacked by cutworms, and many young plants may be lost as a result of the presence of these pests. Fortunately, however, cutworms can be effectively dealt with by the use of poison bran baits. The preparation of these baits is dealt with in Chapter XIII., which contains a detailed account of the life history and control of cutworms, and hence further reference to these pests is unnecessary in the present chapter.

Nematode infestation may also be a serious source of loss, but here again the reader is referred to Chapter XIII. for full details with respect to life history and control. Control of this pest, however, is not nearly so simple as in the case of cutworms, and efforts should be directed to its exclusion from areas in which it does not as yet occur.

The Rutherglen bug is another highly injurious enemy of the tomato in the years in which it occurs in plague proportions, but once more the reader is referred to Chapter XIII. for such details as are available with respect to its life history and control.

Mite infestation occasionally occurs rather abundantly on the tomato plant, the leaves, stems, and fruit all being infested. Attacked plants have a rusty-brown shrivelled appearance that is rather characteristic. The most hopeful control measure in this case is probably to dust with sulphur.

The fruit of the tomato plant is subject to frequent and sometimes very severe attacks by the corn-ear worm (*Heliothis obsoleta* Fabr.). As is the case with all the other insect enemies of the tomato discussed in the preceding paragraphs, this pest has a very wide range of food plants that might almost justify its inclusion in a chapter dealing with general feeders. So far as fruits and vegetables are concerned it is, however, outstandingly a pest of tomatoes, and hence it has been decided to deal with it in the present chapter. Its life history and control will now be discussed in some detail, and consideration will then be given to the following diseases:—Irish blight, Fusarium wilt, Septoria leaf spot, target spot, spotted wilt, and blossom-end rot.

The Corn-ear Worm.

The insect known as the corn-ear worm (*Heliothis obsoleta* Fabr.) is an extremely serious pest of many economic plants, but, as its popular name implies, it has gained particular notoriety as an enemy of corn

or maize. It is one of the most destructive insects associated with cotton in Queensland, and it is also undoubtedly the worst insect pest of the tomato in this State. When associated with the last-mentioned plant it is generally referred to as the tomato caterpillar or "worm." For present purposes attention will be devoted solely to its activities as a pest of the tomato.

The corn-ear worm is notorious, not only on account of its very wide range of food plants but also because of the fact that it has been found to occur in many different countries, and is, in fact, practically cosmopolitan. It belongs to the family of moths known as the Noctuidæ, and is therefore allied to the very destructive species commonly referred to as cutworms and army worms.

Life Cycle Stages.

The various changes through which this insect passes to maturity are typical of all moths, there being four very distinct and easily recognisable stages in its development—(1) egg, (2) larva or caterpillar, (3) pupa or chrysalis, (4) imago or moth.

The eggs (Plate 44, fig. 1) when just laid are pearly white in colour, but as the incubation period advances they darken very appreciably. Their shape somewhat resembles that of a dome, and in size they are about equivalent to that of half an ordinary pinhead.

The larvæ (Plate 44, fig. 2) are whitish when newly emerged from the eggs, but their colour soon changes, and in full-grown specimens it varies very greatly, some being pale green, whereas others are dark brown. A number of longitudinal stripes of different shades usually play a part in the formation of the colour scheme. The larvæ have three pairs of jointed legs on the thoracic segments and five pairs of unjointed abdominal legs; when full-grown they measure about 1½ inches in length.

The pupæ (Plate 44, fig. 3) are of the usual lepidopterous type, being brown in colour and measuring about ¾ inch in length.

The moths or imagines (Plate 44, fig. 4) possess two pairs of wings, giving a maximum wing expanse of about 1½ inches. The colour pattern is sufficiently detailed in the accompanying plate (Plate 44, fig. 4), and hence a written description thereof is unnecessary.

Life History and Habits.

The female moth, after mating, generally lays her eggs singly on the flowers, flower buds, or on the young foliage, thus ensuring that the larvæ, on emergence, will have an abundant supply of suitable food close at hand. Eggs may, however, be laid on other parts of the plant.

The number of eggs laid is generally regarded as being in the vicinity of 1,000, although as many as 3,000 have been recorded. Egg-laying is spread over a number of nights. The incubation period of the eggs in the summer months is about three days, but in springtime six days or even longer may be spent in the egg stage.

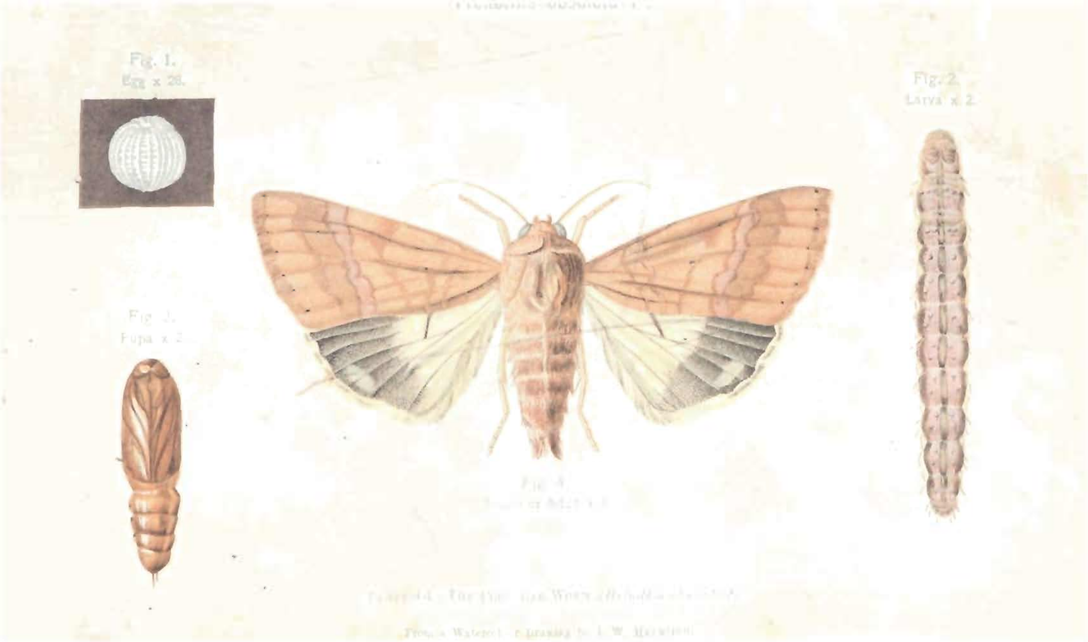


Fig. 1.
Egg x 28.
Fig. 2.
Larva x 2.
Pupa x 2

The newly emerged caterpillars eat the eggshells and then turn their attention to the flowers, foliage, or fruit of the plants on which they occur. The caterpillars may continue feeding on the foliage, but usually they make for the green fruit. The most destructive feature of their feeding activities is the attack on the fruit, which they enter at the calyx end (Plate 45). Each fruit within which a larva is feeding is rendered useless, and, as the larva attacks fruit after fruit, each individual is capable of destroying a considerable quantity of tomatoes in the course of its short larval life. The injury in cases where the larva does not feed within the fruit is much less serious, and the tomatoes so attacked are not necessarily rendered useless. In bad outbreaks 50 per cent. or more of the fruit may be destroyed, and, unfortunately, infestation is not confined to the coast, for losses also occur in the Stanthorpe district. The caterpillars grow rapidly, and moult five times before becoming full-grown. Full size is attained in two or three weeks, and then the insect passes on to the third stage in its life cycle, namely, the pupa.

The full-grown caterpillar drops to the ground and burrows into the soil to a depth of a few inches. It then forms a small earthen cell inside which it changes to the pupa. In the pupal stage a tremendous transformation takes place, and a complete reorganisation of the body contents results in the production of the moth or reproductive stage of the insect. The pupal stage generally occupies ten days or a fortnight in the warmer weather, but in cold weather the time necessary for the completion of that portion of the life cycle may be greatly prolonged. No feeding takes place in the pupal stage.

At the end of the pupal stage the moth emerges from the earthen pupal cell and works its way out of the soil through a channel constructed by the larva prior to pupation. It then mates, lays eggs, and so the life cycle is continued. The moth is generally considered to live for a period of about two weeks. It is nocturnal in its habits, but may occasionally be seen in the daytime. It feeds on the honey of flowers, and is in itself responsible for no damage to tomatoes. The whole life cycle from the laying of the egg to the emergence of the moth occupies from four to six weeks for the spring and summer generations in Queensland.

NATURAL ENEMIES.

Quite a number of natural enemies attack the corn-ear worm, but, unfortunately, they do not exert their maximum influence until summer is well advanced, and accordingly the tomato-grower cannot depend on them for complete control. He must, therefore, supplement the natural control factors by artificial control measures.

The eggs are attacked by three very small wasps, *Trichogramma australicum* Gir., *Trichogrammatoidea rara* Gir., and *Neoteleonomus sp.* A small bug, *Triphleps australis*, also does good work by sucking the contents of the eggs and thus destroying them.

The larvæ are parasitized by four enemies, and two predatory wasps also serve to reduce their numbers.

Insectivorous birds, adverse weather conditions, and diseases also play a part in reducing the corn-ear worm population.

CONTROL MEASURES.

The fact that this pest has a wide range of plants on which it can complete its development suggests that, as one control measure, attention should be paid to other host plants growing in the vicinity of the tomatoes. If these alternative host plants are grown neither for profit nor for domestic use, and are neglected, they will serve merely as excellent breeding-grounds for the pest. They should therefore be destroyed. Should they be grown either for home consumption or for marketing, then they should be subject to suitable control measures that will keep them free from the corn-ear worm. Included in the alternative host plants are maize, cotton, lucerne, tobacco, cowpea, bean, pea, cape gooseberry and rosella.

Tomatoes that have been attacked by this pest should be collected and disposed of by deep burying or by boiling, or by any other suitable measure that will serve to destroy the caterpillars associated with them. In this way a check may be placed on the unduly large multiplication of the later generations.

Rotation is another important measure that may afford some relief from infestation, and if it is practicable to do so it is well to plant tomatoes after a crop that is not susceptible to attack by the corn-ear worm. If that is done the tomatoes will get a cleaner start than would otherwise be the case.

Thorough cultivation in preparation for planting up will lead to the destruction of many of the larvæ and pupæ of this pest, either by direct mechanical injury or by the exposure of these stages to adverse climatic conditions, and to the attacks of predatory enemies such as birds.

Spraying or dusting with arsenate of lead is regularly practised in many districts in Queensland for the control of the corn-ear worm on tomatoes, and much benefit is usually derived from this control measure. The crop must be treated several times at somewhat frequent intervals, the applications commencing not later than the date at which the first fruit appears. Careful observations leading to the detection of heavy egg-laying by the moths will frequently indicate the most appropriate times at which to spray or dust.

Dusting is carried out with a dust gun, and is dependent on suitable atmospheric conditions for success. It should be attempted only when there is little or no wind blowing, and is best undertaken when the dew is still on the plants early in the day. Various brands of dusts are on the market, and some of these have been specially prepared for application to tomatoes. Fruit that has been sprayed or dusted should be cleaned before packing.

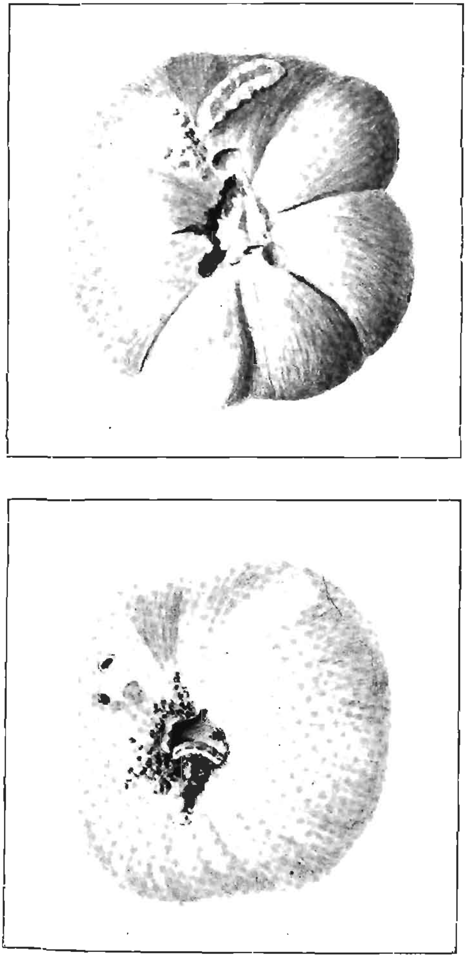


Plate 45.—Tomatoes Attacked by Corn Ear Worm Larvæ.
(From a water-colour drawing by I. W. Helmsing.)

Irish Blight.

Irish blight is commonly thought of as a disease of the potato rather than the tomato, since it was in connection with the former crop that it first reached economic importance. The disease is due to the attack of a fungus parasite, *Phytophthora infestans.* It was apparently introduced into Europe from South America, the original home of the potato, some time prior to 1842, for at this time it has been recorded as being well established in Europe. In 1845 a serious epidemic occurred in both Europe and North America, of which one of the results was the noted Irish famine. Further severe outbreaks have occurred since then when climatic conditions have been suitable. The tomato is a close relative of the potato, and for that reason several of the diseases affecting one have been able to attack the other. Of these Irish blight is an example.

Symptoms.

The first easily noted sign of the disease takes the form of dark-brown patches on the leaves, commonly working in from the margin. If the weather is at all wet these areas will assume the appearance of a soft rot, and enlarge rapidly. Finally the entire leaf may become affected and shrivel up. (Plate 46, fig. 1.) Blackish lesions are also formed on the stem and leaf-stalks. The fungus in this case may produce complete encturing of the part attacked, when the whole of the outer portion of the branch affected will wilt and die. Under moist conditions there will be seen, on the under surface of the leaves and on the stem covering the brown areas, a delicate whitish down formed by the fruiting bodies of the fungus as they project out from invaded tissue.

The grower's attention is usually more especially attracted to the disease when the fruit become affected. A somewhat diffuse light-brown patch arises on the skin of the green fruit. This enlarges and may finally cover a large proportion of the surface, at the same time turning a dark though somewhat mottled brown colour. (Plate 46, fig. 2.) The margin of the discoloured area may be definite or may diffuse gradually into the general green of the healthy skin. On cutting through one of these spots the discolouration will be seen to extend right through the skin of the fruit and may penetrate even the pulp and septa. Very often the fruit rot extends to considerable dimensions before the fructification is produced. This appears during humid weather as a delicate white mould on the surface of the discoloured region. The fruit may sometimes constitute the main part of the plant attacked.

Causal Organism.

The fungus causing Irish blight in its ordinary growing stage is very similar to most other fungi, and consists of clear, slender, branched threads or mycelium, these threads being less than $\frac{1}{1000}$ inch in width. They ramify among the cells forming the plant tissue, absorbing nourishment for themselves, and thus bring about the destruction of the invaded part, producing the symptoms described above.

If the weather is sufficiently moist, the fungus after a few days' vegetative growth will commence to form its fruiting stage. Short aerial threads or hyphæ grow out through the breathing pores situated on the under surface of the leaf and other parts attacked. These branch three or four times, and on the ends of the branches are formed delicate lemon-shaped spores or fungus seeds. (Plate 46, fig. 3.) These spores are produced in enormous numbers, and are so minute that they can easily float about in the air and thus serve to spread the disease throughout the field. Should a spore come to rest on a tomato plant moist with dew or rain, its contents divide up into from six to twelve smaller portions, which escape from the spore-case and swim round in the surface moisture by means of two vibratile filaments. These swarm spores, as they are called, soon come to rest and send out a slender thread known as a germ-tube, which penetrates the surface of the plant and commences once more on a period of vegetative activity within its tissues. If conditions are not suitable for the development of swarm spores, which must have moisture for their existence, the spore itself may sometimes develop a germ-tube direct.

Contributing Conditions.

Unlike those of many fungi, the spores of *Phytophthora infestans* are thin-walled and delicate, and are therefore restricted to certain ranges of temperature and moisture for their development and continued existence. Probably the best temperature for the development of the disease lies between 60 and 70 deg. F. The spores are killed if the temperature approaches 80 deg. F. for any length of time, and at temperatures round about 90 deg. F. the mycelium itself soon dies out in the leaf tissues. For the germination of the spores leading to spread of the disease, abundant moisture is necessary, either in the form of heavy dews or rain with accompanying humid conditions. Thus for the occurrence of an epidemic there must be a certain combination of temperature and humidity. In coastal Queensland a temperature suited to the development of Irish blight is likely to occur only during the cooler months. This period usually coincides with the dry season. Hence this disease in normal years does not reach serious proportions. However, it sometimes happens that a period of wet weather occurs during the autumn, winter, or early spring growing season, and considerable loss from Irish blight is the result. This was well illustrated by the outbreak of this disease in the Bowen district during July and August of 1927. Rain to the extent of 1.8 inches fell on 23rd and 24th July, accompanied by a sudden fall in temperature, the daily maximum from 23rd July to 3rd August ranging from 57 to 77 deg. F., with an approximate daily average of 58 deg. F. With the advent of hot dry weather the loss from blight rapidly diminished. If the weather is exceptionally wet, blight may spread sufficiently to cause serious loss even during warmer months.

Growers should therefore be prepared to take steps to minimise the loss from Irish blight. The precautions necessary will also aid in controlling certain other leaf diseases to which the tomato is subject.

PLATE 46.—IRISH BLIGHT OF THE TOMATO.

Fig. 1, Foliage symptoms. Fig. 2, Fruit rot. Fig. 3, Fruiting stage of the causal organism (*Phytophthora infestans*), highly magnified.

CONTROL.

1. General farm sanitation will go a long way towards the control of most fungus troubles, and should be practised in the case of Irish blight. If leaf disease has been present, the remains of the crop should be destroyed by fire after harvesting is completed. When possible the same ground should not be planted to tomatoes for two years in succession. Tomatoes should not follow potatoes, and *vice versa.*

2. Spraying with Bordeaux or Burgundy mixture has been shown to give an effective control over Irish blight when the spray is properly made and applied. The plants should be sprayed when about 6 inches high, and again as often as necessary to keep the foliage well covered with poison. The number of applications will depend on weather conditions. During periods of wet muggy weather spraying may have to be done every few days, as it is under these conditions that the spores are best able to germinate and the protective covering of spray is liable to be washed off by the rain. The spraying should be thorough, in order to ensure that both upper and lower surfaces of the foliage are covered.

Bordeaux and Burgundy mixture should be used at the 6-4-40 and 6-8-40 formulæ respectively. If applications are to be made at frequent and regular intervals, these quantities can be reduced as mentioned in the chapter dealing with the preparation of these sprays.

Fusarium Wilt.

There are at least four distinct wilt diseases affecting tomatoes in Queensland. These consist of a bacterial wilt caused by *Bacterium solanacearum*, two fungus wilts due to the organisms *Fusarium lycopersici* and *Verticillium alboatrum*, and the virus disease dealt with later. The commonest and most generally distributed of these is the Fusarium wilt, which will be described below.

SYMPTOMS.

Wilting is not always a marked symptom of this common tomato trouble. The lower leaves of the plant usually commence to take on an unthrifty appearance, turn yellow and then brown, and finally dry up. This effect may gradually extend up the stem until finally the whole plant has withered. In other cases the plant will suddenly wilt and die before the drying of the leaves has progressed to such an extent. If seedlings or young plants become infected they may remain stunted from the start, if not dying completely.

CAUSE.

The fungus (*Fusarium lycopersici*) causing this disease can live for many years as a saprophyte on decaying vegetable matter in the soil, and from there enter the tomato plant through injuries to its roots. The fungus grows up through the tissues of the root into the main stem, where it develops chiefly in the large water-conducting vessels, gradually

working up the plant through these. The presence of the fungus affects the vessels to such an extent that the supply of water and food material passing up from the soil is diminished. This leads to the general unthrifty appearance of the plant, and eventually when water conduction is completely stopped wilting takes place. Sometimes only the vessels running up one side of the stem supplying a particular lateral will be invaded, when the leaves of the latter may die while the rest of the plant remains healthy.

If the base of an affected plant be cut across with a clean knife just above ground-level, the fungus-invaded vessels will be seen to stand out as distinct brown patches in the region of the large-celled woody tissue, which in a healthy plant is of a light-green colour. When the bark is peeled off the browning will be observed to extend for a considerable distance up the stem, often running out into lateral branches. (Plate 47, fig. 1.) This discolouration will serve for a quick diagnosis of Fusarium wilt. Somewhat similar symptoms are displayed by plants affected with bacterial wilt, but in this case a slimy bacterial ooze will exude from the cut vessels. Verticillium wilt closely resembles Fusarium wilt in its general symptoms and in the method of attack of the causal organism, but is apparently of much less frequent occurrence than the latter.

The reproductive stage of the fungus is not greatly in evidence. Numerous small sickle-shaped spores may be formed on the surface of old decaying crowns. (Plate 5, fig. 9B.) These are shed into the soil, where they may develop and the fungus live as a saprophyte on decaying vegetable matter until another tomato crop becomes available for attack.

CONTROL.

As the causal organism obtains entrance through the roots, spraying for this particular disease is of no use. The difficulty of effective control is increased by the soil-frequenting habits of the fungus.

1. Pull up and destroy all diseased plants as soon as noticed, in order that the number of spores dispersed into the soil may be reduced to a minimum. The crop as a whole should be removed and burnt as soon as harvesting has ceased.

2. If the land becomes infected it should be subjected to rotation of crops, returning to tomatoes only after at least a three-year interval. As the fungus has been stated to be able to remain in the soil for seven years, a longer rotation is advisable when possible.

3. Use only virgin or sterilised soil for the seed-bed, which should not be made near the site of previous tomato crops.

4. Use resistant varieties. There are now in Queensland—mainly owing to the work of the Northern Instructor in Agriculture, Mr. Pollock—several varieties, including both American and local productions, which in some districts exhibit resistance to Fusarium wilt. Unfortunately, owing to variation in local growing conditions and probably also to the occurrence of different strains of the fungus, the resistance does

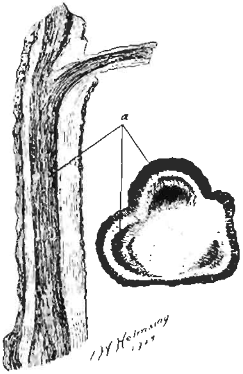


Fig. 1.—Fusarium Wilt of Tomato. Portion of stem with outer layer removed and enlarged transverse section to show darkening of vascular tissue at *a*.

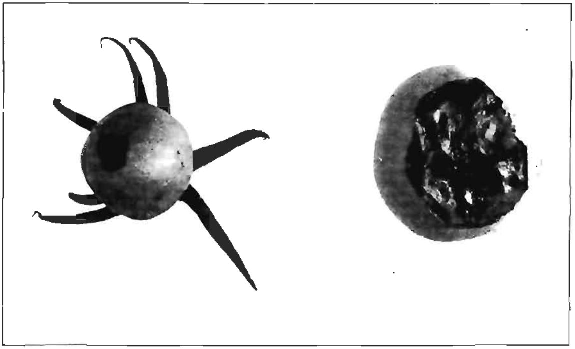


Fig. 2.—Blossom End Rot.

PLATE 47.

not hold good throughout all tomato-growing districts in Queensland. Also, the presence of one or more of the other tomato wilts in a certain locality may cause the use of a Fusarium-resistant variety to be apparently devoid of results. Under the circumstances it will be necessary for each district to try out these varieties for itself. When so doing the growers should be careful to obtain seed from an accredited source. The use of resistant varieties is the most useful means of controlling any disease, and is certainly the best method in the case of Fusarium wilt.

Septoria Leaf Spot.

This disease first appears on the older leaves of the plant as minute grey dots visible on both sides of the leaf but more conspicuous on the lighter under surface. These spots gradually enlarge to about ⅛ inch in diameter. At the same time the tissue first affected dries out to a lighter colour, so that finally the lesion appears as a small circular greyish or light-brown spot bordered with a margin of dark brown. The disease is finally characterised by the appearance of a cluster of fine black points on the grey surface. (Plate 48, fig. 1.) As the spots become older a diffuse yellowing spreads out from their margin until finally the whole leaflet may be involved. These then gradually dry out and wither up. In an affected plant the older leaves will be seen to successively assume a spotted and yellow appearance, followed by drying and death. Finally in case of severe attack a tuft of green leaves at the end of the branch may be all that remains. The dying of the central leaves in this manner may expose the fruit to severe sunscald. Spotting also occurs at times on the stem and leaf-stalks.

Cause.

This leaf disease is caused by a fungus (*Septoria lycopersici*). It is the fruiting bodies of this fungus which appear as the characteristic black points on the leaf-spots. These bodies consist of minute flask-shaped receptacles or pycnidia whose mouth projects out upon the surface where it is just discernible to the naked eye. The walls of these pycnidia are formed of dark closely interwoven fungus hyphæ, and from the inner surface are produced numerous long slender many-septate spores. During wet weather these are exuded in a white sticky column from the mouth of the pycnidia, and are transferred from here to healthy leaves by the splashing of rain, by the wind distributing the dust in which they have been washed, by insects, &c. The spores may also be carried about the field upon the person of field workers.

The control of Septoria leaf spot will be considered in connection with that of target spot, a disease with which it shows considerable resemblance.

Target Spot.

This disease, like Septoria leaf spot, is mainly a foliage trouble, though unlike the latter the fruit may also be attacked at times.

SYMPTOMS.

The first symptoms of an attack are seen in the form of minute dark-brown to black specks scattered, often in only moderate numbers, over the older leaves. These increase in size and become surrounded by a halo of a light-green to a greenish-yellow colour which diffuses into the general green of the leaf. The mature spot usually consists of a clearly defined dark-brown area more or less rounded in shape and from ¼ to ½ inch in diameter. The fungus causing the disease in its extension through the plant tissue has a somewhat intermittent growth depending on weather conditions. The limit of its extension at various times is defined by a number of concentric slightly raised ridges which give to the spot the target-like effect to which the disease owes its name. (Plate 48, fig. 2.) This marking is not always in evidence, and sometimes the spotting as a whole is less definite and of a more diffuse type. The yellowing of the tissue surrounding the spots extends considerably as these become older, and if the number of infections is at all numerous large portions of the leaf may become involved in the discolouration and will eventually wither and dry out. The older leaves are the first attacked, and the result, as in the case of Septoria spot, is seen in the gradual drying out of the leaves from the base upwards as the fungus spreads higher up the plant. As with this other disease, scalding of the unprotected fruit is likely to follow.

A similar type of spotting is also produced on the stem and leaf-stalks. The lesions here are of a more elongated shape and are without the yellow border.

The same fungus may cause large black sunken spots on the fruit. These areas are usually covered in their later stages with a black velvety mass of mould-like growth due to the presence of various saprophytic organisms. Fruit infection does not appear to be of common occurrence in Queensland.

CAUSE.

The organism producing this disease is *Alternaria solani*, a fungus which is responsible for a similar trouble sometimes affecting the potato crop. The spores of this fungus are brown club-shaped bodies divided up by several transverse and an occasional longitudinal septa. (Plate 5, fig. 9e.) They are produced on short conidiophores which project in clusters from the surface of the leaf, the whole being faintly visible as a dusky growth over the older diseased spots.

The spread of target spot takes place by dispersal of the spores from the diseased leaf surface with the aid of rain, wind, &c., as in the case of Septoria spot.

CONTROL OF SEPTORIA LEAF SPOT AND TARGET SPOT.

The fungi causing both Septoria and target spot are much alike in regard to their method of attack and effect on the plant, and both diseases are amenable to the same treatment.

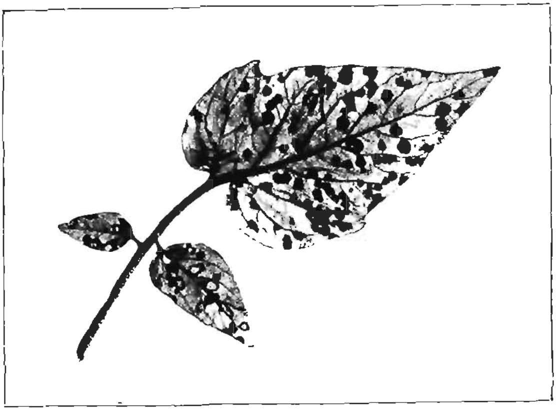


Fig. 1.—Septoria Leaf Spot.

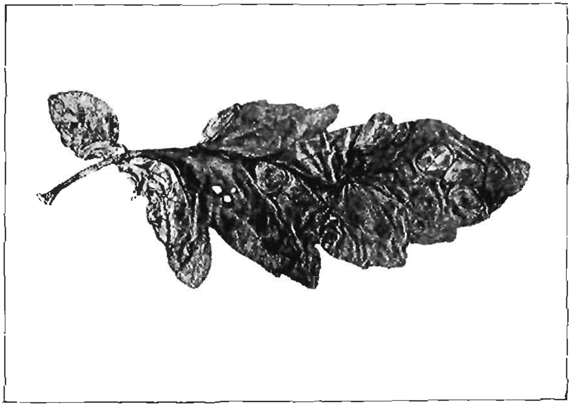


Fig. 2.—Target Spot.

Plate 48

Each affects the older leaves, more especially when the plant is approaching a mature size or is in a poor state of vigour owing to the presence of nematodes or unsuitable growing conditions. For this reason these diseases are often considered to be merely the natural result of ageing. However, considerable loss may be experienced through diminution in vigour and shortening of the productive life owing to the attack of one or both of them. Much damage is occasioned also should the mature fruit become sunscalded through being exposed by the premature loss of the central leaves.

The fungi concerned in these diseases may pass from season to season on old infected plant remains left undestroyed from a previous crop. When once infection of a new crop has taken place, further batches of spores are continuously produced from the affected spots and are spread by wind and rain, &c., through the whole field, and falling on clean plants create further centres of infection. Efforts for control should therefore proceed along the following lines:—

1. Destroy all old plant material by fire as soon as the crop is off.

2. Spray regularly with Bordeaux mixture in order to prevent infection. Young plants may be attacked in the seed-bed and the planting of infected seedlings may be the cause of trouble later in the field. Spraying should therefore commence in the bed when the plants are 3 to 4 inches high. The strength for use in this early stage should be reduced to a 3-4-40 formula. Later applications should be made with the 6-4-40 mixture as for the control of Irish blight. If desired Burgundy may be substituted, using the 3-4-40 and 6-8-40 formulæ respectively.

Spotted Wilt.

Spotted wilt is a disease only recently recorded from this State, but it has already caused considerable loss to tomato-growers in some localities. This tomato malady first appeared in Victoria in the 1915-1916 season, and was later fully described by Brittlebank, the Victorian Plant Pathologist, who named it "spotted wilt" on account of its characteristic symptoms. It has now been reported from all the Australian States. In Queensland the disease has so far been definitely noted only in certain tomato-growing districts in the vicinity of Brisbane. The amount of loss sustained on different farms varied from an odd plant to 50 per cent. of the crop.

Symptoms.

Affected plants can often be picked out from a distance owing to the development of a somewhat drooped appearance. This is due to a tendency of the main leaf-stalk to curve down and the leaflets to curve upwards at the edges. New growth may also be more attenuated than normal. Sometimes the plant as a whole has a bronzed appearance when the spotting mentioned below is much in evidence. These appearances, however, may be induced to a certain extent by other diseases, and the characteristic symptom of spotted wilt is the presence on the leaves

of numerous small brown spots which produce in the early stages a distinct mottled pattern. These spots may be rather indefinite and somewhat diffuse, but more typically they are roughly circular in shape, varying in size from minute dots up to an area of about ⅛ inch in diameter. (Plate 49.) They are variously scattered on the upper and sometimes the lower surface of the leaf between the main veins. The younger leaves situated towards the outer ends of the branches are usually the first to show this marking. The spots if numerous may coalesce, and the surrounding tissue then gradually turns yellow and dries out so that the leaf presents a withered appearance. (Plate 49.) Dark-brown surface streaks usually linear or broadly linear may occur on the leaf-stalks and stems. On scraping, this discolouration will be seen to be restricted to the surface layer of cells. In some cases the fruit may show brown to blackish greasy-looking markings of varying extent which do not usually penetrate the flesh for any great distance. The symptoms may appear on from one to all the branches. In the latter case the plant will finally present the appearance of complete wilt—a condition which is sometimes assumed very rapidly. Very vigorously growing plants are perhaps the most affected.

Spotted wilt in its later stages, when the leaves are all dead and drying, may be distinguished from the common Fusarium wilt by the absence of the brown fungus-invaded patches of woody conducting tissue which are seen in the case of the latter when the lower portions of the main stem are cut across.

Cause.

Repeated attempts have been made by workers in the Southern States to find a fungus or bacterial parasite which might be the cause of spotted wilt, but without success. In the absence of a definite parasite of this nature, the disease differs from most common tomato troubles. It has been demonstrated recently by H. A. Pittman, working at the Waite Agricultural Research Institute, Adelaide, that spotted wilt belongs to the virus type of plant disease. As regards the nature of the malady, spotted wilt therefore resembles bunchy top of bananas. In this type are grouped a number of diseases presenting certain points of similarity but whose causal agents are so minute that there has so far been developed no means of viewing them with certainty. What little is known about these organisms has therefore to be inferred from the reactions obtained in various experiments with the plant juice in which they have been shown to occur. The way in which the infective agent is transmitted from infected to healthy plants varies with the individual disease. Some virus diseases may be spread by inoculating healthy plants with the juice from a diseased one. In others it is necessary to graft a portion of the affected plant on to the healthy. Many are spread by means of sucking insects. Pittman has discovered the fact that spotted wilt is transmitted by a species of thrips (*Thrips tabaci* Lindeman). This is a minute insect which easily escapes casual observation. It spreads the disease during its normal feeding habits by transferring juice containing the causal agent or virus from a diseased to a healthy plant.

Spotted Wilt.

PLATE 49.

Leaflets from a

Control.

No certain means of control has yet been demonstrated. Spraying with a fungicide is of no avail on account of the nature of the disease. As an affected plant may harbour the virus with which healthy plants can be inoculated, such sources of infection should be kept to a minimum. The following recommendations are designed to reduce the loss due to this wilt.

1. Pull up and burn any diseased plant as soon as it appears. A regular inspection of the plot should be undertaken at frequent intervals for this purpose. It is not sufficient to remove a single branch because this is the only one bearing symptoms, since the rest of the plant may be harbouring the infectious agent even though not showing signs of the disease. Unfortunately, under certain conditions the plant may be a bearer of the virus without displaying the usual symptoms. This, however, should not be used as an argument for neglecting systematic destruction.

2. Spray with a contact insecticide such as Black-leaf 40 for the control of the thrips.

3. Avoid excessive use of strong nitrogenous manures, which tend to make the plant more susceptible by producing excessively succulent growth.

4. Clean up and burn the remains of the crop as soon as it has ceased to be profitable, as an odd infected plant left over from crop to crop may be the means of perpetuating the disease. This precaution will also help to control the various fungus diseases of the tomato. It is also advisable to keep the farm as free as possible from weeds and the remains of other crops which may harbour the thrips.

Blossom-end Rot.

The appearance of this disease in a severe form occurs only during certain seasons when the peculiar meteorological conditions necessary for its development are manifested.

Symptoms.

In the first instance a light-brown surface discolouration appears at the apex or blossom-end of a green developing fruit, and gradually spreads until a somewhat irregular circular area of an inch or more in diameter becomes involved. (Plate 47, fig. 2.) The affected region becomes dark brown or leaden brown in colour. The tissue is firm and somewhat shrunken, often sufficiently to cause a definite depression. Internally the flesh of the tomato may be darkened for some little distance below the surface, but except when the fruit becomes invaded by secondary organisms there is no soft rot.

CAUSE.

Attempts to isolate fungal or bacterial organisms from the early stages of this disease are usually unsuccessful, and it is the general opinion at the present time that the trouble is of a physiological nature and not due to the presence of parasites. The symptoms appear to be brought about when the plant is subjected to an erratic water supply such as occurs when periods of wet are followed by hot dry weather.

It has been suggested that under these conditions the foliage, in order to make up its own requirements, withdraws water from the fruit with the result that some of the apical cells collapse giving rise to the symptoms noted.

The excessive use of organic nitrogenous manures may also be a contributing factor in the development of blossom-end rot.

CONTROL.

By means of good cultivation and when available irrigation, maintain, so far as possible, an even supply of soil moisture throughout the growth of the crop. Avoid excessive use of strong nitrogenous manures.

Control of Tomato Diseases.

After noting the various measures that may be advocated for the control of the common tomato maladies, it will be seen that loss due to any or all of these (with perhaps the exception of spotted wilt) may be diminished by attention to the routine farming practices of sanitation, careful selection of the seed-bed, rotation of crops, good cultivation, and if possible irrigation, together with a regular spraying programme using Bordeaux or Burgundy mixture.

CHAPTER XII.

PESTS AND DISEASES OF VEGETABLES.

The following pests of vegetables are dealt with in this chapter:—The potato tuber moth, the leaf-eating ladybird, the cabbage aphis, the diamond-back moth, the pumpkin beetle, the bean fly, and the onion thrips. Other sources of serious losses in vegetables are cutworms, Rutherglen bug, and nematodes, but these pests being wellnigh omnivorous are more appropriately dealt with in the following chapter, which is devoted to the consideration of such general feeders.

Pathological problems for discussion in this chapter include the following:—Downy mildew, powdery mildew, anthracnose, and wilt of cucurbitaceous plants, i.e., melons, cucumbers, pumpkins, &c. Bacterial black rot, blackleg, and downy mildew of cabbages and cauliflowers also require consideration, and anthracnose of the bean will be discussed.

The Potato Tuber Moth.

The potato tuber moth (*Phthorimœa operculella* Zell.) occurs throughout the various States of the Commonwealth, and is generally considered the most destructive insect enemy of the potato in this country. It was recorded as early as 1854 in Tasmania, and Tryon discussed its ravages in Queensland in 1889. There is much controversy with respect to the native home of this pest, some writers believing it to be of North American origin while others consider its home is North Africa. It is an insignificant moth belonging to the family Gelechiidæ.

Nature of Injury.

The injury inflicted by this pest is of a twofold nature, for it may attack the aboveground portion of the plant or it may attack the tubers. Injury to the former is due to the larvæ of the moth mining in the leaves and leaf-stalks, and tunnelling in the stems. This damage to the foliage and stems may be quite appreciable, but is not generally considered nearly so serious as the injury to the tubers. In the tubers this pest, in its larval stages, may burrow and tunnel to such an extent as to very greatly depreciate their market value.

Plants Attacked.

Among the plants recorded as being attacked by this pest are the following:—Potato, tobacco, egg plant, cape gooseberry, and tomato. It is, however, of importance as a pest only on the first two mentioned plants. On the potato it is, as already indicated, referred to as the potato tuber moth, whereas, when attacking tobacco, it is more commonly called the tobacco-leaf miner or the tobacco splitworm. In addition to

attacking the abovementioned plants of economic importance, it also feeds on a number of weeds belonging to the Solanaceæ or potato family, included among these being the common nightshade (*Solanum nigrum*).

LIFE CYCLE STAGES AND LIFE HISTORY.

The oval-shaped pearly-white eggs are extremely minute and can just be seen by the naked eye. They may be laid on the leaves or stalks or on the tubers, and may also be found on the sacks in which infested potatoes are stored. When laid on the tubers they generally occur in clusters, and are usually laid in the eyes or at a scar on the surface of the tubers. On the foliage they do not occur in clusters, but may be found occurring singly, generally on the underside of the leaf. In the open, egg-laying does not usually take place during the day, but it is believed that in dark stores it takes place quite readily at all hours. Life-history studies in North America have shown that the moth lays from 150 to 250 eggs over an egg-laying period of from one to two and a-half weeks.

At the end of the usual incubation period the larvæ hatch from the eggs, and if these have been laid on the leaves the larvæ commence mining in the foliage between the upper and lower surfaces of the leaves. If the eggs have been laid on the tubers, the larvæ eat through the skin and either tunnel under the skin or burrow towards the heart of the tuber, eventually forming tunnels which may be 2 or 3 inches long. Infestation is most serious when it takes the form of burrowing towards the heart of the tuber. When full-fed the larva is slightly less than ½ inch in length, and is white in colour with a faint pink tinge.

The full-grown larvæ generally leave the tubers to pupate, although they may do so just within the entrance to their tunnels. The pupa is formed within a silken cocoon, and may be found on the outsides of the tubers or between folds of sacking or indeed in any of at least half-a-dozen other situations. Pupæ formed by the larvæ that have been mining in the leaves and tunnelling in the stalks may commonly be found among the dead withered leaves or under lumps of soil. The pupa is slightly more than ¼ inch in length and is dark brown in colour.

The usual transformation processes take place within the pupa, and eventually the insignificant greyish-brown moth emerges. It has a wing-spread of about ½ inch and a body-length of about ¼ inch. The moths mate, egg laying takes place, and so the infestation continues.

CONTROL MEASURES.

Control measures should aim very largely at safeguarding the tubers, firstly when they are in the soil, secondly while they are being harvested, and thirdly when they are subsequently in storage. Tubers in the soil may be attacked by this pest, and hence it is desirable to adopt cultural practices that will minimise the danger at this stage. For this reason it is a wise precaution to plant as deeply as is practicable, and to

keep the thoroughly pulverised soil well hilled up so that the tubers will not be exposed. Once the tubers are exposed infestation will become serious. As the common nightshade weed is a host plant of this pest, it should as far as possible be destroyed.

At harvesting certain precautions should be adopted, among the more important of which are the following:—The potatoes should be bagged and removed as soon as possible after digging, and furthermore the bags should be sewn up as soon as they are filled. The tubers should never be left overnight in the field exposed to the attacks of the moths, because if that is done many thousands of eggs may be laid on them, and subsequently severe losses will be experienced in storage when the larvæ hatch out of the eggs. Furthermore, the harvested potatoes should on no account be covered with the tops, because, if these are infested, the larvæ will desert the fast withering leaves and stems and burrow into the tubers. The potato tops, according to Australian authorities, should be burned as soon as practicable after the harvesting of the tubers. An American investigator, however, recommends that such a practice be abandoned, because of the destruction of the parasites that may be associated with the tuber moth. The question of parasite control raised by this recommendation seems worthy of some further investigation in Queensland, to determine to what extent useful parasite control exists in this State. The harvested tubers should, if possible, be kept in a store-room to which access by the tuber moth is not readily obtainable. The not infrequent practice of leaving tubers heaped up in an exposed condition in an unclosed store-room merely invites serious trouble.

Fumigation of tubers that have become infested with potato tuber moth larvæ has been recommended in the United States, carbon bisulphide being used at the rate of 2 lb. to 1,000 cubic feet, the duration of fumigation being 48 hours. It is said that under American conditions the treated tubers are not injured, and that the whole of the larvæ and moths and the great majority of the eggs and pupæ are killed. The fumigation may have to be repeated if infestation reappears.

The Leaf-eating Ladybird.

The ladybird beetles or Coccinellidæ constitute one of the most important families of insects, largely on account of the fact that the great majority of their species are carnivorous, beneficial insects, feeding, in both their larval and adult stages, on aphids and scale insects. There is, however, one small group of the ladybirds, members of which are phytophagous—i.e., they feed on plant tissue. This group is known as the Epilachninæ, and is represented in Australia by two species that are quite commonly met with, namely, *Epilachna 28-punctata* Fab. and *Epilachna guttato-pustulata* Fab. The former is decidedly the more important of the two, and it is the species that is generally referred as the leaf-eating ladybird.

The leaf-eating ladybird has a wide range of food plants, and in Queensland it commonly attacks potatoes, tomatoes, and pumpkins. Rock-melons and cucumbers are also attacked, and it may frequently be found feeding on nightshade (*Solanum nigrum*), which is also a weed host-plant of another potato pest, namely, the potato tuber moth. The trumpet flower (*Datura stramonium*) is another weed on which this ladybird may commonly be found feeding.

Nature of Injury.

The damage inflicted by this beetle is due to the feeding of both the beetle and the larva of the species, the former feeding freely on the upper and lower surfaces of the leaves, while the latter concentrates its attention on the lower surface. The larva feeds in a very characteristic fashion which is well depicted in the accompanying illustration (Plate 50, fig. 5). It eats a fairly long narrow strip of tissue on the underside of the leaf, but in doing so it does not eat completely through to the upper surface. It then cuts a second strip alongside the first one, the two strips being separated from each other by only a very thin ridge of uneaten tissue. The process is repeated again and again until a comparatively large ragged patch is eaten out of the underside of the leaf, only the thinnest layer of tissue being left intact on the upper surface. The beetles may eat right through the tissue of the leaf.

In recent epidemics this pest has been present in such numbers that the foliage in many cases has been practically destroyed, and even the stems of the attacked plants have been seriously injured. Where extensive injury is inflicted on the foliage there must obviously be a very much reduced yield of the edible product of the plant attacked, i.e., the potato tuber, the tomato fruit, or the pumpkin.

Life Cycle Stages and Life History.

The yellow eggs (Plate 50, fig. 1) are laid in clusters on the foliage, the number laid in each cluster in the field having varied from 13 to 45 during a recent outbreak of this pest. The eggs are typical ladybird eggs, being elongate oval in shape and measuring about $\frac{1}{8}$ inch in length. The surface of the egg is beautifully reticulated, but such a detail can be observed only with the aid of a lens. The eggs are glued to the foliage at their broader ends. The incubation period during the outbreak already mentioned was four days.

The larva (Plate 50, fig. 2) is a most extraordinary spiny-looking creature, and when full-grown it measures about $\frac{1}{3}$ inch in length. The under surface of the body is yellow in colour, while the upper surface is similarly coloured except for the fact that the yellow colour is broken by rectangular brown areas at the base of the many-branched spines which give the larva its awe-inspiring aspect. The larva possesses three pairs of legs. The larval period lasts for about three weeks, and during that growth period it moults four times.

PLATE 39.—THE LEAF-EATING LADYBIRD (*Epilachna 28-punctata F.*).

The pupa (Plate 50, fig. 3) is about ¼ inch in length, and may be found securely fixed to the leaf, stalk, or main stem. A conspicuous feature of this pupa is the fact that the last larval skin, moulted when pupation takes place, is attached to the abdominal extremity of the pupa. The pupa itself possesses dark-brown markings broken by creamy-coloured patches. The pupal period during the warmer months in Queensland has been found to extend to only four days.

The oval-shaped beetle (Plate 50, fig. 4) is about ¼ inch in length and is yellowish brown in colour. The wing covers bear a number of very conspicuous black spots, whence the name *28-punctata* is derived. The number of these spots is not, however, constant, and they may vary from 12 to 14 on each wing cover. In occasional specimens the yellowish-brown body colour is replaced by a much darker shade which gives the beetle a very dark brown appearance, and in these specimens the black spots do not stand out so conspicuously as in those that are normally coloured. Like other ladybird beetles, this species exeretes an unpleasant, evil-smelling, yellowish fluid when it is handled. Recent life-history investigations by Miss Temperley showed that in the laboratory the female beetle may lay as many as 252 eggs.

CONTROL MEASURES.

Outbreaks of this pest are fortunately not long-lived, but while they last they may be very severe. Experience has shown, however, that it yields readily to treatment with arsenical sprays. Whenever it is noticed becoming abundant on the foliage of any of its host plants of economic importance, steps should be taken to spray the same with arsenate of lead, using the formulæ given in the chapter dealing with insecticides. Dusting may be adopted as an alternative to spraying.

NATURAL ENEMIES.

A hymenopterous parasite, *Stomatoceras colliscutellum* Gir. (Plate 50, fig. 6), occurs in the pupæ of this pest, and it may be of some little service in limiting the abundance of the insect, but it is not thought to be at all effective as a control factor. Miss Temperley, in the course of recent life-history studies of this pest, was led to suspect that the very widely distributed and much-maligned little ant, *Pheidole megacephala* Fab., was responsible for the destruction of many of the eggs of the leaf-eating ladybird. Certainly in several countries to which this small ant has been introduced it has exercised a high degree of influence on the native insect fauna, and it may be that in Queensland it is including the leaf-eating ladybird in the list of insects suffering from its presence.

The Cabbage Aphis.

The so-called cabbage aphis (*Brevicoryne brassicæ* L.) on occasions becomes quite abundant in Queensland cabbage crops, and when it does so it is by no means an easy pest to control. In addition to attacking cabbages it may also commonly be found on cauliflowers, turnips, brussels sprouts, radishes, and kohl-rabies.

Once it has become established in a cabbage crop it is capable of very rapid multiplication if conditions are favourable, and eventually large colonies of this greyish-blue insect can be seen on both the upper and lower surfaces of the leaves of infested plants. Like all aphids this pest lives by sucking the sap of its host plant, and if it is present in large numbers the plants will become seriously stunted and produce obviously sickly, yellowish-looking leaves. In severe infestations, some of the more heavily attacked plants may actually die off.

So far as is known, the life history of this pest has not yet been worked out in detail in Queensland, but some considerable amount of attention has been devoted to it elsewhere, particularly in North America. These investigations have shown that its life history is somewhat complicated, but the details thereof need not be discussed in these notes. Both winged and wingless females occur. The insect is a somewhat pear-shaped, soft-bodied, slow-moving individual, the body being covered with a white waxy bloom.

Control Measures.

With respect to control, this is generally attempted by the use of either nicotine sulphate or kerosene emulsion sprays, preference now being given to the former insecticide. When the aphids are actually wet with the spray the result is quite satisfactory, but in practice difficulties exist in its application. The body of the aphis, as already mentioned, is covered with a fine film of wax which renders effective wetting of the insect a matter of some considerable difficulty. Furthermore, the aphids are so protected in their colonies on the leaves that it is frequently difficult to reach all of them with the spray.

Nevertheless, in spite of these adverse factors, spraying with nicotine sulphate, "Black-leaf 40," reduces infestation appreciably, thus allowing the young plants to continue growing. The formula that is generally recommended is ¾ pint of "Black-leaf 40" in 100 gallons of water to which 4 or 5 lb. of soap is added. Kerosene emulsion may be used if nicotine sulphate is not readily available. The preparation of this emulsion has already been dealt with in the chapter devoted to the discussion of insecticides.

Natural enemies play some part in checking this pest in Queensland, and not infrequently the aphis is heavily attacked by small wasp parasites. In spite of the presence of these beneficial insects, however, the aphis, as has been said, quite frequently gets out of hand. In such a case spraying must be adopted, and in doing so it is highly desirable to commence operations as soon as there are signs of the aphis becoming unduly abundant.

A plate to illustrate this insect is not yet available, but readers who are not familiar with it may obtain some idea of its appearance by referring to an allied insect, the banana aphis, which is illustrated on Plate 37. The aphis in this case is of course very highly magnified.

The Diamond-back Moth.

The diamond-back moth (*Plutella cruciferarum* Zell.) is probably the most serious pest of cabbages in Australia. It is one of a large number of undesirable insect introductions from Europe, where it is well known as a pest not only of cabbages but also of turnips and other crops. It attacks cabbages, cauliflowers, turnips, brussels sprouts, radishes, and horse radishes, as well as some other crops of importance, and it has also been recorded from several garden flowers and from a number of weeds. It has gradually become distributed throughout the world, both in the tropic and the temperate zones. In Queensland it is considered primarily a pest of cabbages.

The very minute eggs are laid on the leaves of the cabbages, and the larvæ or caterpillars hatch out after a brief incubation period. These larvæ feed on the foliage, and eventually the attacked leaves become riddled with holes at the spots where feeding has taken place. The larvæ grow fairly rapidly, and after passing through a series of moults they attain full size when they are slightly less than ½ inch in length. They are green in colour, and are rather slender, active, spindle-shaped caterpillars clad with only a few short bristles. The full-grown larvæ cease feeding, and then pupate on the leaves in very beautiful, silken, lace-like cocoons the strands of which are so loosely woven together that the pupæ can be distinctly seen within. The moths emerge from the pupæ after the usual transformation processes have taken place.

The moth is rather a pretty little greyish-brown species with a wing-spread of about ⅔ inch, the name "diamond-back" having been conferred upon it as a consequence of the appearance the male moth presents when at rest with the wings folded. The pattern of the front wings is such that when they meet on being folded there appears a chain of three diamond-shaped marks. The wing pattern is less definite in the female moth and the same chain effect is not produced. The moth when at rest tilts its wings in a very characteristic fashion.

Control Measures.

Spraying is largely adopted for the control of the diamond-back moth, and a certain measure of success attends this procedure, although it cannot be claimed to be thoroughly effective. Arsenate of lead sprays are used against this pest, but, on account of the possible danger to the consumer, cabbages should not be sprayed with this poison after they have commenced to heart.

Kerosene emulsion has been recommended by some investigators as useful for keeping down infestation in young plants, and nicotine sulphate has been recorded as being similarly successful. Watering the cabbages with very hot water is also said to be a useful procedure, but for obvious reasons it can be adopted only on a relatively small scale. It is claimed that the water can be applied sufficiently hot to kill the caterpillars without appreciably injuring the fleshy foliage. When

cabbages are grown commercially it would generally, however, be necessary to employ one of the three insecticides just mentioned, namely, arsenate of lead, nicotine sulphate, or kerosene emulsion. To achieve success, spraying must be repeated several times and must be commenced early in the life of the crop.

Stricter attention to farm hygiene than is sometimes given by cabbage-growers will also be productive of beneficial results. All too often the grower cuts the marketable cabbages, and leaves the useless ones to rot on the ground and to act as breeding grounds for myriads of cabbage moths, which naturally immediately infest any new area he may plant up in the vicinity. Where it is practicable to do so, this source of danger should be eliminated.

The cabbage-grower attempting control along the lines indicated in the preceding paragraphs will obtain some measure of relief, but it must be admitted that the control of this pest is as yet on a somewhat unsatisfactory basis.

The Pumpkin Beetle.

The pumpkin beetle (*Aulacophora olivieri* Guérin) is an important pest of cucurbitaceous plants, and it may very frequently be found in large numbers on the vines, feeding on both the foliage and flowers. It is quite the most serious Queensland insect enemy of pumpkins and allied plants.

It commonly attacks pumpkins, water-melons, rock-melons, cucumbers, and vegetable marrows. On one occasion it was also recorded in New South Wales as a pest of ripening cherries, but such an attack appears to be of a somewhat abnormal nature, and for present purposes it may be regarded exclusively as a pest of cucurbitaceous plants such as those mentioned.

The beetle, which is responsible for the destruction of the flowers and foliage, is a very conspicuous insect measuring about ¼ inch in length, the length being about twice as great as the width. It is orange-yellow in colour with two very distinct large black blotches on each wing-cover. This species is frequently referred to as a ladybird, but it is quite distinct from the ladybird beetles (Plate 50), which are different in outline, being decidedly rounded whereas the pumpkin beetle is definitely elongate in shape. In the leaf-eating ladybird, damage to the foliage is inflicted by both the beetles and their larvæ, but, in the case of the pumpkin beetle, foliage and flower losses are caused by the beetles alone, for their larvæ have been recorded as possessing root-frequenting habits.

Control Measures.

With respect to the control of this pest, a certain measure of success may be obtained by spraying or dusting the attacked plants with arsenate of lead. As an alternative to spraying or dusting, the beetles, where numerous, may be collected by shaking them into shallow containers

in which a mixture of kerosene and water has been placed. This operation is most successfully performed when the beetles are sluggish and do not readily take to flight on the infested plants being jarred; it should therefore be carried out in the early morning. It is particularly important to destroy any beetles that show up early in the season, and the expenditure of energy involved in the operation will generally be amply repaid if the young plants are periodically carefully examined, and the beetles found associated with them destroyed.

Young plants may be protected from attack if the seedlings are covered with some form of netting which has been stretched over a suitable framework to prevent the beetles gaining access to the seedlings. Such a protective measure, however, is practicable only on a small scale. It will, nevertheless, tide the seedlings over a very dangerous period when the attack of a few beetles may very seriously injure or even kill the infested plant.

A further control measure that has been suggested by some investigators is to liberally dust the plants with wood ashes or lime, or alternatively with road dust. This procedure is said to act as a satisfactory repellent in outbreaks of ordinary severity.

The Bean Fly.

As a result of the presence of the bean fly (*Agromyza phaseoli* Coq.), the growing of beans in coastal Queensland is often rendered quite unprofitable during the warmer months of the year. Bean plants which may be growing under ideal conditions of soil and climate are all too frequently noticed to be in a far from flourishing condition. The plants may be wilted and stunted, and they may eventually fall over or break off and die.

The unhealthy condition of these plants is in all probability due to the presence of bean-fly infestation, and such a suspicion can be confirmed quite readily by an examination of the stalk of an affected plant. In typically infested plants the stalks will be found to be abnormally swollen in many places, and furthermore they will be seen to be frequently split open where the swellings occur. An examination within the tissue of these swollen fissured areas will usually speedily disclose the presence of the creamy-coloured maggots responsible for the damage. These feed within the tissue of the stalks and produce the effects just described. When full-grown the maggots pupate in the stalks, the pupæ being enclosed within small yellowish-brown puparia. At the end of the pupal period the very insignificant black flies emerge.

Control Measures.

It has been found in practice that the control of this pest is a matter of very considerable difficulty. The use of sprays does not offer any appreciable prospect of success, but eventually a repellent may be found that will justify application with the object of preventing the female fly

from laying her eggs on the bean plants. In the meantime, however, the grower of beans must fight this pest by strict attention to market garden hygiene.

The bean-fly population may be appreciably reduced by the prompt destruction of useless infested plants. These should be pulled up and burned, instead of being allowed to remain in the ground to breed out further batches of flies from the maggots and pupæ which they are harbouring. The time devoted to the application of this quite simple control measure will generally be time well spent.

It has also been found that some measure of relief may be obtained by hilling up the plants so that they may have a chance of producing adventitious roots above the injured portions at the base of the stem.

The Onion Thrips.

The only insect pest of onions that commonly comes under the notice of the entomologist in this State is the onion thrips (*Thrips tabaci* Lindeman). This destructive little insect is a relative of the species that is responsible for "rust" in bananas, and some general idea of its appearance may be obtained by reference to the figures (Plate 29) illustrating the life-history notes on the banana pest in question.

The onion thrips is a very delicate yellow or yellowish-brown insect possessing two pairs of characteristically fringed wings and measuring about $\frac{1}{25}$ inch in length. It is practically cosmopolitan, and is a pest of a very wide range of economic plants, although for present purposes it will be considered solely as an enemy of onions.

The adult and nymphal or immature thrips both attack the leaves of the onion plant. They lacerate the surface of the foliage and feed on the plant sap where the surface has been injured. At each point of attack a small white blotch develops, and the whole plant may eventually be covered with these silvery or white blotches. The leaves wilt and fall over, and a reduction in the yield of the crop must obviously be expected when the thrips infestation is severe. The condition produced as a result of the feeding of this pest is often referred to as "white blast."

Control Measures.

When the onion crop is infested by this thrips, spraying with nicotine sulphate should be practised. This procedure is generally productive of good results in the case of young crops, but in the older crops satisfactory application of the spray is more difficult, and results are not so good. Spraying with nicotine sulphate is, nevertheless, quite worth while even in the case of older plants. Several applications of the spray are usually necessary in order to produce the desired results.

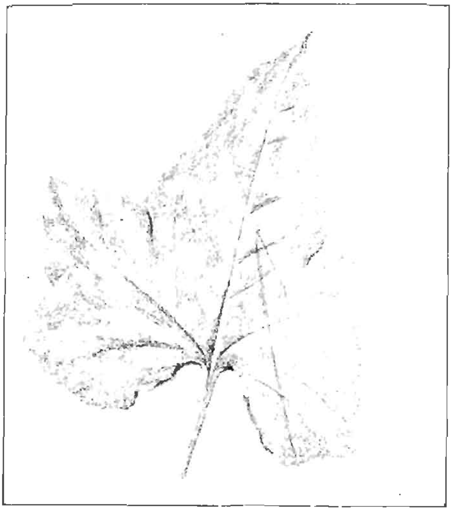


Fig. 1. Cucumber Leaf affected with Downy Mildew.

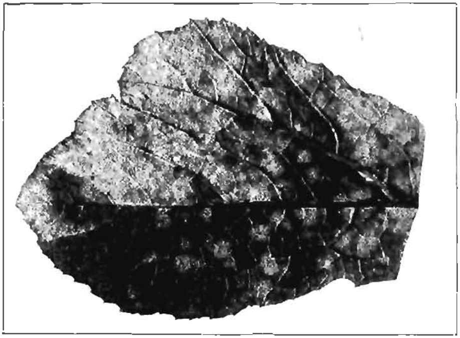


Fig. 2.—Powdery Mildew on the Marrow.

PLATE 51.

Downy Mildew of Cucurbits.

Downy mildew is probably the most serious disease affecting cucurbits in this State. Rock-melons and cucumbers suffer most severely while marrows are also occasionally attacked. In moist warm weather favourable to the spread of the fungus, little more than a week is needed for a field to be practically wiped out.

Symptoms.

The disease commences first on the older leaves of a vine near the centre of a plant and gradually works out from these along the runners. In its early stages downy mildew shows up as small diffuse and somewhat indistinct greenish-yellow spots. These enlarge until they become delimited by some of the veins of the leaf to more or less definite angular areas of about ⅛ to ¼ inch across. (Plate 51, fig. 1.) The colour of the invaded area turns to a more distinct yellow or light yellowish brown. If the spots are numerous they may coalesce to form larger discoloured areas which give, especially in the case of cucumbers, a yellow appearance to the plant as a whole. The affected portions gradually turn brown and dry out, and the leaf contracts upwards about the main veins giving a characteristic claw-like effect. The wilting of the leaves extends out along the runners, leaving a small number of the younger leaves at the end unaffected or showing only early symptoms.

When once a vine becomes badly affected the development of any fruit present comes to a standstill, nor are any more produced. Sunscald may result from the loss of leaves.

Cause.

The disease is brought about by a fungus parasite (*Pseudoperonospora cubensis*) allied to those fungi producing downy mildew of the grape vine, cabbage, &c. Often there is no external indication of the fungus causing the disease spots, but during moist weather the fruiting stage appears on their under surface as a very delicate whitish down which changes to a light purple brown as the spores mature. When infection is heavy the whole of the under surface of the leaf may have a downy coat of this colour. The fructification consists of delicate conidiophores branched in a somewhat tree-like manner which project two or three together from the stomata. From the tip of each of the branches is produced a thin-walled oval spore which easily becomes detached and blown about, thus serving to disseminate the fungus.

Control.

The disease may be checked by systematic spraying with Bordeaux mixture. This spray applied at the usual strength is found to cause burning of some cucurbits, and it is therefore advisable to use instead a 3-4-40 formula. Care must be taken that both upper and under surfaces of the leaves are covered.

It will be noted that the disease makes its first appearance on the older leaves towards the centre of the plant. Spraying should therefore commence when the plants are small, in order to prevent infection starting in this region. By this means spread of the disease may be retarded sufficiently to enable the crop to be harvested. Once downy mildew has got a firm hold in well-advanced vines little can be done to save them.

Any diseased material should be burnt, and a field on which a mildewed crop has grown should not be planted again to cucurbits for a year or two.

Some varieties appear to show resistance to downy mildew, but there is not yet available satisfactory data in this connection so far as Queensland is concerned.

Powdery Mildew of Cucurbits.

Powdery mildew is a disease to which all cucurbit crops are subject, though the cucumber, marrow, and pumpkin probably suffer most. The disease is caused by a fungus (*Oidium erysiphoides*) which is one of the ectoparasitic type, living as it does on the exterior of the host plant. The interlaced mycelial threads, together with the fructification, form diffuse white patches on both the upper and lower surfaces of the leaves. These patches spread and merge into one another until the whole leaf may become covered with a white floury coat. (Plate 51, fig. 2.) The lesions are not of the definite restricted area seen in the case of downy mildew. The affected leaf turns a greenish yellow and then yellow usually over fairly large areas, and finally dries out. As in the case of downy mildew, the older leaves are attacked first, the infection proceeding from the centre out along the runners.

The fructification of the fungus consists of straight unbranched conidiophores developed direct from the surface mycelium. Transverse septa laid down in these cut off successive cells which become constricted off to form thin-walled oval spores. These may remain loosely attached for a time, forming a chain. (Plate 4, fig. A.)

Control.

Owing to the superficial growth habit of the fungus causing this disease, spraying with lime sulphur or dusting with sulphur will provide control. To be effective, both sides of the leaves must be covered.

Water-melon Anthracnose.

Anthracnose is a disease which may attack water-melons, cucumbers, and rock-melons. The amount of loss sustained depends largely on weather conditions. During a hot dry season the disease may not obtain a firm hold until after the vine has ceased to be productive. In a wet season considerable loss may be experienced through fruit disfigurement and reduction in yield from loss of foliage. The disease is caused by one of the anthracnose group of fungi (*Colletotrichum lagenarium*).

Fig. 1.—Cabbage Blackleg.

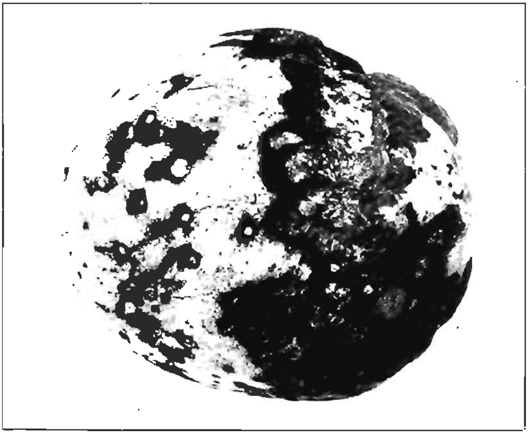


Fig. 2.—Water-melon Anthracnose.

PLATE 52.

SYMPTOMS.

All parts of the plant may be attacked, the invasion commencing from the centre of a hill and working outwards. The symptoms vary somewhat on the different hosts. In the case of the water-melon there appear on the leaf scattered, sharply defined, dark-brown to almost black spots of a roughly circular outline and of varying size up to nearly ½ inch in diameter. Stem lesions take the form of linear or broadly linear brown and somewhat shrunken patches in the centre of which there frequently appear clusters of light-pink pustules formed by the spore masses of the fungus concerned. The combination of leaf and stem injury results in the withering of the older leaves from the centre of the vine outwards, possibly at the same time exposing developing fruit to sunscald.

On the fruit small light-brown slightly raised spots appear. These enlarge, turn dark brown, and become somewhat sunken. At the base of the depression appear the pink spore masses characteristic of the disease. Infection of young fruit may lead to malformation. On older fruit the anthracnose lesions may be sufficiently numerous to coalesce and form large irregular disfiguring patches. (Plate 52, fig. 2.) Often other organisms are able to invade the fruit through anthracnose spots and set up extensive rot.

On the cucumber the leaf lesions are less conspicuous, owing to their being of a light-brown rather than black colour. The fruit are not so commonly attacked as in the case of the water-melon.

CONTROL.

1. Infection of a crop often results from the use of a field in which there remains refuse from a diseased crop of the previous year. Cucurbits should therefore not be planted on the same land for two years in succession.

2. The grower should be careful if selecting his own seed to make sure that the fruit used does not bear anthracnose lesions from which spores may chance to contaminate the seed.

3. Spraying cannot be relied on to act as a sure prevention, owing to the difficulty of covering the under surface of all leaves. Bordeaux mixture of 3-4-40 strength if systematically applied will, however, check the disease sufficiently to enable a crop to be taken off. An application should be made as soon as the vines begin to run, and another when the first fruit have formed. Further applications will be necessary if the weather is at all wet especially should the disease makes its appearance in the field.

Water-melon Wilt.

Water-melon vines will sometimes wilt off suddenly for no apparent reason; the plant may previously appear perfectly healthy. On cutting across the base of the stem of a wilted plant the large water-conducting vessels will be seen to exhibit a yellowish-brown discolouration. This

is due to invasion by a fungus (*Fusarium niveum*), a parasite allied to the one causing Fusarium wilt of tomatoes. This fungus can live for long periods on vegetable mould in the soil, and from there will invade the melon plant per medium of injured roots. The fungus then travels up through the vessels of the stem, causing sufficient damage to these to eventually bring about the wilting of the vine.

Fungi with the same habits sometimes cause trouble of a similar nature in other cucurbitaceous crops.

CONTROL.

Owing to the soil-frequenting habits of the fungus, little can be done beyond rotating an infested field for several years to crops other than those belonging to the cucurbit family.

Black Rot of Cabbage and Cauliflower.

Black rot is probably Queensland's commonest cabbage disease. The plant may be attacked at all stages of growth, and when the disease becomes well established heavy loss is the result. The disease is favoured by warm weather, and is therefore most serious on a crop grown during the summer months.

CAUSE.

Black rot is caused by a bacterial parasite (*Pseudomonas campestris*). This is a minute rod-shaped organism with a single vibratile flagellum developed from one end, by means of which progress through the plant tissue becomes possible. The bacteria enter the plant through the minute water-pores which are to be found situated round the margin of the cabbage leaf. On a cool night small drops of surplus water will be seen exuding from these openings. The bacteria reaching these drops quickly multiply and find their way through the pores into the leaf. The injuries caused by the various leaf-eating insects will also serve as a point of entry.

SYMPTOMS.

As a result of this method of invasion there is seen, as a first symptom of attack, light-brown areas of dying tissue extending in from the margin of the leaf or surrounding insect wounds. The affected region gradually advances along the direction of the main veins towards the midrib, and the brown invaded tissue dries out to a thin papery consistency. The bacteria travel chiefly within the water-conducting vessels of the veins, which they discolour to such an extent that the latter stand out as black lines over the brown areas. (Plates 53 and 3, fig. 3.) Eventually the whole leaf may dry up. The bacteria meanwhile travel down the midrib and leaf-stalk into the main stem of the plant, and from this can invade other parts. In this manner they may pass up the stem into younger leaves, and so produce dark blotches in the white centre of leaves of an apparently sound head. The organisms may multiply in the water-conducting vessels of the stem to such an extent that the normal function of these can no longer be performed, with the result that affected plants are usually markedly stunted.

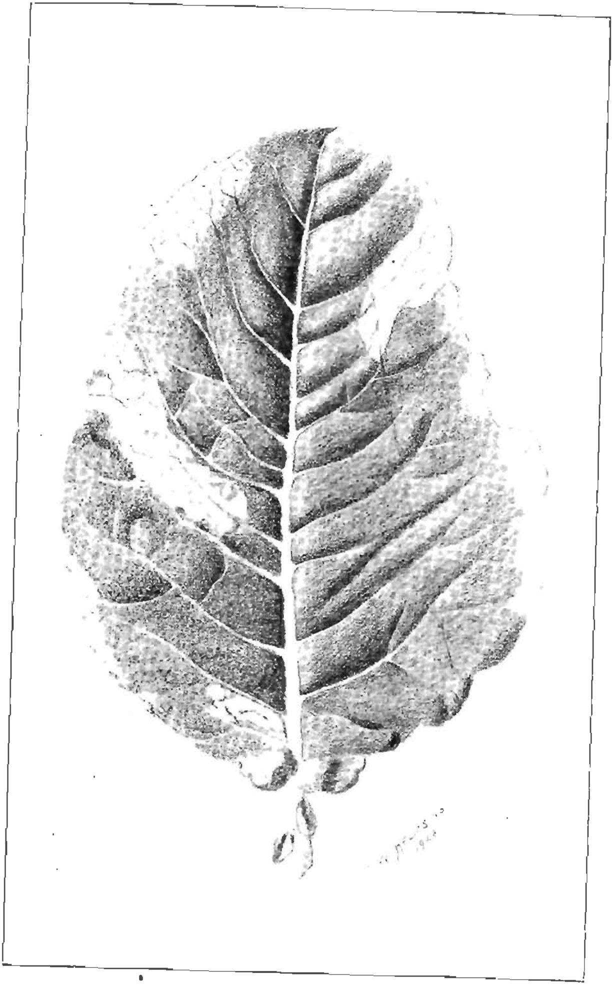


PLATE 53.—BLACK ROT OF CABBAGE.

Although the black rot bacteria only produce a dry rot, they may open the way for the invasion of various soft rot organisms which finally bring about a rapid, foul-smelling, wet rot.

On cutting across the base of an affected leaf or through the crown of the plant, the black ring of bacteria-filled vessels usually stands out plainly, and constitutes for diagnostic purposes perhaps the most characteristic symptom of the disease. (Plate 54, fig 2.)

Almost all cruciferous plants are subject to black rot, though the cabbage and cauliflower are the ones seriously affected. In the cauliflower there is a tendency for the affected areas of the leaf to be restricted in extent, and they may eventually dry up and drop out.

Control.

In this connection it may be pointed out that the bacteria causing black rot may contaminate the seed, where they can remain unaffected by desiccation for many months. They can also live in the soil for a year or two in the absence of a living host. The field and seed-bed can therefore easily become infested by contact with refuse from a diseased crop.

The following control measures should be practised:—

1. Obtain seed from a district in which seed-borne diseases are not known to exist. If the origin is doubtful, the seed should be disinfected by soaking for thirty minutes in a 1 to 1,000 solution of corrosive sublimate (see Chapter VI.). The seed is then rinsed thoroughly in clean water and spread out to dry. Care must be exercised when using corrosive sublimate, as this chemical is a deadly poison.

2. Select a site for the seed-bed some distance removed from land that has previously grown cabbage or other cruciferous crops. Be sure that manure used in the bed is free from any chance of contamination. If a suitable site cannot be obtained the bed should be disinfected as described in Chapter VI.

3. Practise crop rotation. After producing a cruciferous crop the land should be kept free from cabbage, cauliflower, or related plants for two or if possible three years.

4. Insects may be the cause of an increase of the disease, by creating means of entrance and also by directly carrying the bacteria from plant to plant. These should therefore be kept in check by suitable spraying or dusting.

Blackleg of Cabbage.

This disease is caused by a fungus (*Phoma lingam*) which, like the black rot organism, may attack the plant at any period of its growth from the seedling stage to maturity. Cabbages and cauliflowers are both liable to serious infection, while the fungus may attack to a less extent other related crops such as turnip, radish, and several cruciferous weeds.

Symptoms.

The disease commonly appears first in the seed-bed, where its presence is manifested by a stunting and yellowing of the plants, and frequently by damping off. In an affected plant an area of rot appears on the stem below the seed-leaves. This usually becomes sunken and of a dark colour. The fungus may advance rapidly through the tissue until the stem is cinctured and the seedling wilts.

In other cases infection may take place in the bed, but the disease does not develop sufficiently to prevent the seedling from being planted in the field. Here the fungus will develop further and destroy the tissue of the stalk below the leaves, gradually extending its attack down the rootstock. The affected region becomes shrunken and black, giving the appearance from which the name is derived. (Plate 52, fig. 1.) Later there will appear numerous minute black specks scattered over the affected area. These are the rounded fruiting bodies or pycnidia of the fungus causing the disease, and their appearance serves to distinguish blackleg from other diseases of the cabbage producing somewhat similar symptoms. The root system may be entirely destroyed, leaving only a tapering stump. Sometimes a tuft of lateral roots will be developed above the affected region, and these for a time lend some support to the plant.

The fungus may also attack the leaf-stalks and leaves, forming on the latter irregular light-brown areas speckled over with the black pycnidia. Spores from these leaf lesions may be splashed or blown on to the growing seed-head, and there develop and cause infection of the seed-pods and seeds. Seed contaminated in this way is a frequent cause of the introduction of blackleg into clean areas.

The effect on the plant as a whole is to cause a yellowing and dying of the outside leaves, which shrivel up and remain attached to the stem. (Plate 52, fig 1.) The diseased plant is usually markedly stunted as compared with healthy individuals, and may eventually wilt off completely during a spell of dry weather.

Control.

The chief means by which infection of a new crop takes place are—(*a*) By the use of infected seed; (*b*) by sowing in an infected seed-bed; (*c*) by planting in an infected field. Spores may remain capable of germination associated with old diseased cabbage refuse in the soil until this has completely rotted away.

In the matter of the source of primary infection, there is then close correspondence between blackleg and the bacterial disease previously described. As would be expected from this, the control measures for the two diseases are very similar.

1. Obtain seed from a district in which seed-borne disease is not known to exist, or else treat the seed to destroy the fungus with which it may be contaminated. Sterilisation of the seed with corrosive sublimate

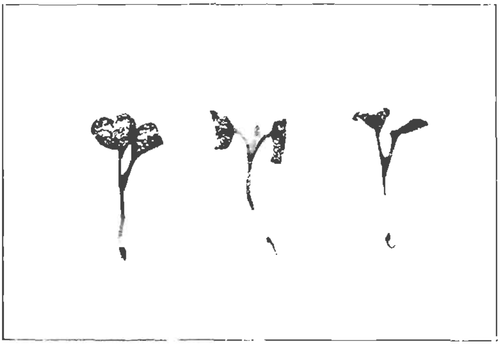


Fig. 1.—Downy Mildew on Cabbage Seedlings.

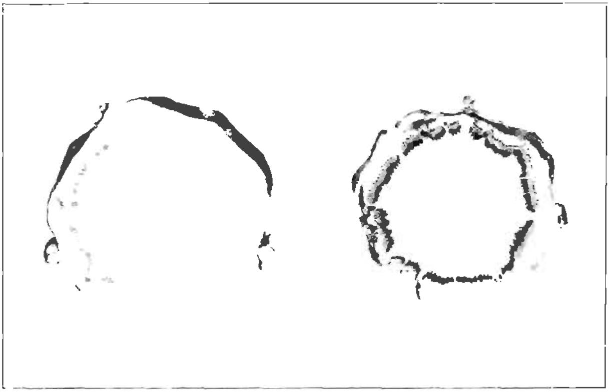


Fig. 2.—Transverse section of the stem of a healthy Cabbage (left), and a Black Rot infected Cabbage (right), to show characteristic blackening of the vascular tissue by the bacteria.

PLATE 51.

as for black rot may be practised, but, owing to the fact that the fungus mycelium may actually penetrate the internal tissues of the seed, this method does not always give satisfactory control. A better plan is to adopt a hot-water treatment, in which the seed is immersed for 25 minutes in water held at 122 deg. F. At this temperature the spores and mycelium of the fungus are killed while germination of the seed is scarcely interfered with. The operation necessitates the employment of considerable care to ensure an even temperature.

2. Use only fresh or sterilised soil for the seed-bed, and let this be situated as far as possible from the location of previously diseased plants. Watering the seed-bed by carefully flooding the surface rather than by overhead spraying will help to prevent the distribution of the fungus throughout the bed.

3. Spraying the seedlings with weak Bordeaux mixture (4-4-40), combined if desired with arsenate of lead, will help to keep this and other seed-bed diseases in check.

4. Practise a rotation of crops, allowing at least a three-year interval between plantings of a cabbage, cauliflower, or related crop. The land will be more quickly freed from infectious material if the remains of the diseased crop are carefully removed and burnt and the ground well ploughed.

Downy Mildew of Cabbage.

Downy mildew is a disease in this country mainly confined to the seed-bed. Growers of cabbage and cauliflower often find it difficult during a wet season to raise sufficient seedlings for their needs, owing to the ravages of this disease.

Symptoms.

A white downy growth appears on the under surface of the young leaves, which soon turn a dark colour and shrivel up. (Plate 54, fig. 1.) Finally the whole seedling dies down. The trouble will spread rapidly through a bed leaving few or no healthy plants.

Cause.

The disease is due to the attack of a fungus (*Peronospora parasitica*) which is of a similar type to those organisms causing downy mildew of the grape vine, cucumber, &c. The white mildew characteristic of the disease is produced by numerous clusters of fungal fructifications. These consist of short, upright conidiophores which branch in a somewhat arborescent manner at the top, and develop from the tips of the terminal branches delicate, oval, thin-walled spores. The spread of these spores by wind and rain serves to distribute the disease throughout the seed-bed. Another form of spore may be found within the tissue of the plant. This is of a rounded, thick-walled, sexually produced type

known as an oospore. This serves as a resting spore, and enables the fungus to live through adverse conditions of environment and infect succeeding crops.

CONTROL.

1. The seed-bed should be located on new ground, as is required for the control of other cabbage diseases.

2. Avoid a thick growth by thin sowing in order that air may circulate freely among the plants.

3. Watering should not be excessive, and is best done by flooding the ground rather than by overhead spraying.

4. Cabbage seedlings should be sprayed with Bordeaux mixture of 4-4-40 strength (combined if desired with arsenate of lead) to check the various seed-bed diseases.

Bean Anthracnose.

Anthracnose has long been recognised as a serious disease of the French bean, and is known to occur in practically all countries in which this crop is grown. Most serious epidemics occur during successive wet seasons, especially if the rain comes during cool weather.

SYMPTOMS.

All parts of the plant may be attacked, though the lesions when occurring on the pod are most conspicuous and characteristic. Here the disease first appears as minute brown spots. These enlarge radially as the fungus producing them advances through the tissue until they are ¼ inch or more in diameter. As the cells of the pod tissue are invaded they die and collapse, and the spot becomes in consequence more or less depressed. The central sunken portion is usually dark-brown almost black in colour, and is surrounded by a margin of lighter brown. Under moist conditions the centre of the spot will be covered with clusters of pinkish pustules representing the fruiting stage of the fungus concerned in the injury. (Plate 55.) The leaves may exhibit brown irregular patches chiefly in connection with the veins of the under surface. Dark-brown cankerous areas are formed on the seedling leaves and lower portions of the stem as a result of seed infection. The spotting on the pod may spread in storage when beans are subjected to long-distance consignment.

CAUSE.

Bean anthracnose is caused by the attack of a fungus parasite (*Colletotrichum lindemuthianum*). The fruiting bodies of this fungus are very readily produced on the affected areas during moist weather. Mycelial threads become massed together at certain points just below the dead epidermis, forming the bed or stroma characteristic of the anthracnose fungi. From the stroma, short, closely growing, peg-like

PLATE 55.—BEAN ANTHRACNOSE.

conidiophores are developed which cut off at their apex single clear oval spores. (Plate 5, fig. 8.) The production of numbers of these spores finally ruptures the overlying layer of plant tissue. The individual spores are held together in a mass by a mucilaginous secretion, and these form the pinkish coloured pustules mentioned above. A shower of rain will free the spores and transfer them to healthy plants.

When the pods are attacked the fungus is frequently able to penetrate through to the seed, which becomes invaded by the mycelial threads. Seed infested in this manner may be somewhat malformed, and usually bears brown or black patches of varying size and shape. The fungus may remain within the dry seed in a dormant state until the latter is subjected to moist conditions suitable for germination. It will then commence to develop further and soon proceeds to the formation of the fruiting stage. Affected seed is frequently too much injured to permit of germination, but should this take place the spores formed on the primary point of invasion may be washed on to the young growth or base of the stem, causing further lesions which may result in the stunting or death of the young plant.

Effect.

The grower often reckons his loss from anthracnose only on the basis of the amount of discard necessary on account of pod disfigurement. In addition to this there have usually been losses due to poor germination of infected seed, death of affected seedlings, and general reduction in productiveness of diseased plants.

Control.

1. Anthracnose has received the attention of many workers, and it has been clearly shown that the chief danger of an attack of this disease lies in the use of infected seed. The grower should therefore obtain his seed from a crop in which anthracnose has not appeared. Failing this, a selection should be made of seeds from pods which show no sign of any blemish which might be attributed to the presence of this disease. For this purpose a regular grower might well keep a small seed-plot which could be more easily kept free from anthracnose by removal of affected plants and regular spraying. The picking over by hand of seed whose origin is uncertain, removing any showing spots or blemishes, is sometimes practised. While this lessens the number of seedling infections, the method is not sufficiently efficient to act as a substitute for selection in the pod. A simple and trustworthy means of seed sterilisation for this disease has not yet been forthcoming.

2. Do not select for bean-growing land having a low damp situation. Sow the plants as thinly as economically possible, in order to reduce the moist conditions arising from a fall of dew or rain and to lessen the chance of spreading. If beans are to follow on the same land next

season, all refuse from a diseased crop should be removed and burnt, as the fungus can pass from one season to the next on such material. If a rotation of crops can be practised so much the better. A bean crop should not be worked when the plants are wet, as spores are then very liable to be carried about the field on clothes, implements, &c.

3. Spraying regularly and thoroughly with Bordeaux mixture of 4-4-40 strength will control the disease. It is, however, doubtful whether in many instances the value of the crop would warrant this procedure. In the case of a small plot grown for seed purposes, spraying may be carried out to advantage.

4. The breeding of resistant varieties would appear to be the most promising means of dealing with this disease. Unfortunately there is as yet no data in this connection so far as Queensland is concerned.

CHAPTER XIII.

GENERAL FEEDERS.

Certain pests and fungus diseases have such a wide range of food plants that the selection of any one of the earlier chapters as the most appropriate one in which to discuss each particular pest or disease would have presented many difficulties. In the circumstances, the best way out of the difficulty seemed to be to deal with these general feeders in a chapter specially devoted to their consideration.

Some of the insect pests now discussed are of outstanding importance, but the diseases dealt with are not quite so important, although they are undoubtedly responsible for serious losses.

The following entomological problems will be discussed in some detail:—Cutworms and army worms, nematodes, Rutherglen bug, and yellow peach moth. Pathological items are represented by Armillaria root rot and Sclerotium crown rots.

Cutworms and Army Worms.

The larvæ of many moths belonging to the family Noctuidæ have long been known as very destructive enemies of a wide range of economic plants. The feeding habits of certain of these larvæ or caterpillars have earned for their species the name of cutworms, on account of their habit of feeding on the stems of their host plants at or near ground-level, and thus severing the aboveground portion of the plant from its root system. Other closely allied species of Noctuidæ have acquired in a most marked degree the habit of frequently migrating in great numbers in their larval stages from field to field, and when that is the case they are commonly referred to as army worms.

Important Queensland Species of Cutworms and Army Worms.

Among the more important species that may be worthy of mention in these notes is the cutworm that was so destructive in the spring of 1926—namely, *Euxoa radians* Guen. In its life history and feeding habits it may be regarded as a typical cutworm, and it has accordingly been selected for brief description as a representative of this class of pest.

Euxoa radians was responsible for nearly all the losses sustained in the spring epidemic of 1926; fortunately, losses in 1927 were very slight, and so far no spring epidemic has occurred in 1928.

The army worms are well represented in Queensland by such species as *Cirphis unipuncta* Haw. and *Cirphis loreyi* Dup., both of which have developed very pronounced army worm habits.

Life History and Feeding Habits.

Comparatively few details have been published with respect to the life history and feeding habits of *Euxoa radians.* It is, however, at present the subject of an intensive investigation by an officer of this department, and it is hoped that much additional information thereon will shortly be available. In the meantime, the following brief outline will probably suffice.

The small, circular, pearly-white eggs have been found in moist soil under low-growing weeds. They hatch after a brief incubation period, and the observations to date indicate that the young larvæ hatching from these eggs generally, but not invariably, feed on the delicate foliage of the weeds under which the eggs were laid—e.g., pigweed and bullhead. As the larvæ grow older they turn their attention to economic plants, and these are frequently destroyed or seriously injured in large numbers.

The larvæ of cutworm moths generally shelter in the soil during the day at a depth of 1 to 2 inches, and in this respect *Euxoa radians* is typical. The cutworms come out to feed shortly after or about sunset, and in the case of well-grown plants they will climb up into the foliage and, if unchecked and in large numbers, the cutworms may completely defoliate the plants on which they are feeding. When young plants or seedlings are attacked the base of the stem is a favourite point of attack, and it is frequently nibbled through or ring-barked, thus causing the seedlings to topple over or wither off.

The nocturnal feeding habits of these cutworms frequently lead to failure to detect the cause of the loss just described. Hence, whenever seedlings are falling over in the manner mentioned or extensive defoliation of plants is taking place without any ostensible reason, it is well to scratch away the soil at the base of the attacked plants to see if the presence of cutworms is the explanation.

The cutworms attain full size in about four weeks during the late spring and early summer months, and in the process of growth they moult several times. The full-grown cutworms of this species are about 1½ inches in length and are stout, fleshy grubs that are only very sparsely clad with extremely small hairs. When dug out of the soil their colour varies to some considerable extent, for while some specimens may be aptly described as being of a dirty grey-green colour, others might more appropriately be called dirty brown suffused with pink. The cutworms possess eight pairs of legs, three of which are jointed legs on the thoracic segments, the other five pairs being fleshy unjointed legs situated on the abdomen.

Having attained full size the cutworms now form earthen cells in the soil at a depth of 1 or 2 inches below the surface, and in these cells they transform to pupæ. The pupæ, which are about ¾ inch in length, are light brown in colour when first formed, but there is a very appreciable darkening as the pupal period advances. The duration

Fig 1 × 1½

Fig 2 × 1½

Fig 3 × 1½

Fig 4 × 1½

Fig 6 × 1½

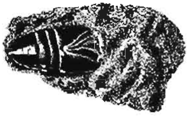


Fig 5 × 1½

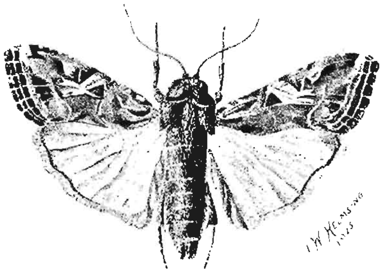


Fig 7 × 2

PLATE 56.

Prodenia litura Fabr.

Fig. 1, Larva, lateral view, × 1½. Fig. 2, Larva, dorsal view, × 1½. Fig. 3, Pupa, ventral view, × 1½. Fig. 4, Pupa, lateral view, × 1½. Fig. 5, Pupa within earthen cocoon, × 1½. Fig. 6, Imago, wings closed, × 1½. Fig. 7, Imago, wings expanded, × 2.

of the pupal period is about a fortnight during the late spring and summer months. No feeding takes place during this stage, and it functions entirely for the reorganisation of the internal tissues, as a result of which reorganisation the moth, which is the reproductive stage in the insect's life cycle, is produced.

The moth is a stout-bodied, unattractive looking insect with a wing spread of 1½ inches, the body length being about ⅝ inch. The fore wings are brown with conspicuous darker brown or blackish brown spots and streaks, while the hind wings are much lighter in colour, being almost white except for a small brownish marginal area.

It is believed that the life cycle of *Euxoa radians*—i.e., from the laying of the egg to the emergence of the moth—occupies about seven weeks in the summer months. The number of generations that may occur each year in Queensland has not been ascertained, but it would appear that the spring generation is the one most to be feared.

The life cycles of the army worm species, *Cirphis unipuncta* Haw. and *Cirphis loreyi* Dup., are somewhat similar in their fundamental details.

Illustrations of the various life-history stages of *Euxoa radians* are not yet available. On Plate 56, however, the larva, pupa, pupal cell, and moth of an allied leaf-eating species, *Prodenia litura* F., are figured, and from these figures the reader can form some rough idea of the general appearance of the life-cycle stages of Noctuid moths.

Plants Attacked.

An extremely large range of plants are subject to attack by cutworms and army worms, and it may be said that hardly any cultivated crop escapes an attack of some varying degree of severity at least in certain seasons.

In departmental records of cutworm and army worm attack, mention is made of the following cultivated host plants:—Cabbage, cotton, grape vine, grasses in general, lucerne, maize, millet, oats, onions, potato, tomato, strawberry, sugar-cane, and wheat.

Control Measures.

When an outbreak commences it is well to take immediate steps to deal therewith, because very heavy losses may be sustained in a comparatively brief space of time.

Fortunately, there are distinctly effective means available for handling these cutworm pests, perhaps the most satisfactory of which is the use of poison bran baits. The preparation of these baits is dealt with in detail in the chapter on insecticides.

The bait prepared in the manner described is best applied late in the afternoon, so that it may be fresh and palatable when the cutworms come out to feed at night. The bait may be broadcast over the infested

area, or it may be applied by dropping about half a teaspoonful of the mixture near to but not touching each plant to be protected. The amount of bait to be used per acre will vary to some extent with the degree of infestation and also with respect to the number of plants to be protected per acre, but generally some 50 lb. of the bait will suffice for the treatment of one acre if broadcast lightly. Where the cutworms are present in very large numbers much heavier applications will be necessary.

It should hardly be necessary to emphasise the fact that caution must be exercised in the application of the bait, because the Paris green contained therein is a very poisonous substance. Before it is applied steps should be taken to ensure that no domestic animals, e.g. poultry, can obtain access to the bait.

As an alternative to the use of poison bran baits, attacked plants may be sprayed with arsenate of lead, but the former method is more satisfactory as it kills the cutworms without sacrificing some of the plant tissue in doing so. When spraying is adopted, a certain proportion of the plants may be destroyed before the cutworms are poisoned, and furthermore it is not safe to spray attacked plants which may shortly be used for foodstuffs.

If these pests are on the march in army worm fashion, and are moving from one cultivated area to another, it will generally be found that poison bran bait scattered a few yards in front of the line of advance will be effective in checking the migration.

A further measure that is frequently adopted when these pests are on the move is to plough a furrow a short distance in front of the line of advance, the steep straight side of the furrow being the one that is most distant from the marching army worms. A little poison bran bait is scattered in the foot of the furrow, or in some cases small holes are dug in the bottom of the furrow at intervals of 10 or 12 feet. The advancing caterpillars will fall into this furrow, feed on the poison bran bait and die, or, where bait is not used, they will wander up and down the furrow in search of a means of escape, and fall into the small holes where they can be killed either mechanically or by the use of a little kerosene. It is obviously essential that the furrow should be so prepared that there is no chance of the caterpillars crossing it.

Natural Enemies.

A number of natural enemies of the cutworm *Euxoa radians* have been recorded in Queensland, these being a very small wasp parasitic on the eggs, namely *Schedius euxoa* Gir., a Braconid wasp parasitic on the caterpillars themselves, a predatory Sphegid wasp *Ammophila suspiciosa* Sm. also attacking the caterpillars, and finally a Tachinid fly similarly parasitic. Birds also doubtless take a heavy toll of these pests.

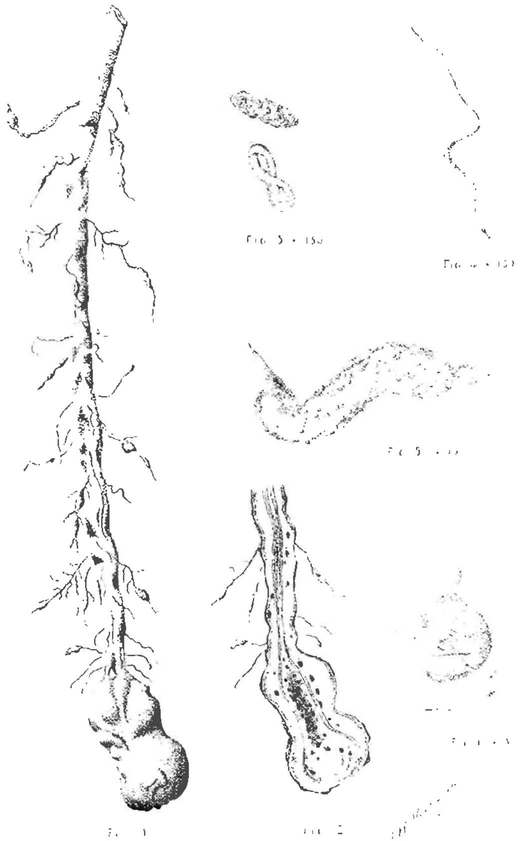


PLATE 57.—NEMATODES.

Fig. 1.—Infested Banana root.
Fig. 2.—Longitudinal section of Banana root showing Nematode infestation.
Fig. 3.—Eggs in different stages of development.
Fig. 4.—Larva.
Fig. 5.—Female.
Fig. 6.—Female (later stage).

Root Knot or Nematode Root Gall.

Nematodes or eelworms belonging to the species *Heterodera radicicola* are responsible for the development of the peculiar malformations occurring in root knot or nematode root gall. These extremely minute animals are found in enormous numbers in the soil in many districts in this State, and records of their destructive activities have been obtained from centres as far apart as Cairns and Coolangatta. The list of economic and other plants attacked by them is a very formidable one, and their presence in the root system is frequently associated with disastrous consequences to the plants attacked.

Appearance of Infested Plants.

An examination of the root system of infested plants usually yields ample and conclusive evidence of the presence of the parasitic organism. The typical feature in an attack by this species of nematode is the occurrence of extremely swollen or distended areas (Plate 57, figs. 1, 2; Plate 58, figs. 1, 3) at various points throughout the root system. The swellings or enlargements may be found occurring singly and at considerable intervals on the roots, or, on the other hand, they may be so close to each other as to give practically the whole of the root system a most peculiar and abnormally thickened appearance. These typical swellings are produced as a reaction to the irritation set up by the activities of the nematodes in the root tissue.

It is well to point out at this stage that, in the Leguminosæ or pea and bean family, certain beneficial root nodules are produced by a totally different organism. These nodules result from the presence of the nitrogen-fixing bacteria that are found in association with the root system of the Leguminosæ, and they must be regarded as being entirely beneficial. The root knots or nematode root galls on the other hand are frequently very detrimental to the welfare of the attacked plants.

The beneficial bacterial nodules may be distinguished by the fact that they are generally small or moderate-sized spherical bodies, which can usually be readily broken off from the sides of the rootlets on which they are found (Plate 58, fig. 4). The root knots or nematode root galls, on the other hand, are swellings in the roots themselves and they are not readily detached therefrom. The difference in appearance between bacterial nodules and the nematode-induced root knots or galls is well indicated in figs. 1, 3, 4, Plate 58.

The roots are not invariably the only portion of the plant attacked, because in the case of the ordinary potato the tubers are often infested, the whole surface not infrequently being covered with a series of swellings which give to the potato a characteristic "pimply" appearance (Plate 58, fig. 2). In addition to the attack on the tubers, the roots of the potato may be infested just as in other plants.

Effect on Infested Plants.

The effect that is produced by root-knot infestation varies very materially. Many of the species of plants included in the category of those that are attacked show but little evidence of the infestation in their roots, and indeed they appear to suffer little or no injury from the presence of the parasite. Other species of plants frequently show very considerable numbers of root galls on the roots, but, even so, in their case there is no definite evidence of serious damage arising therefrom. The third class is the most important for present purposes, for the species of plants included therein are subject to heavy infestations associated with very severe losses.

The galls that occur in the roots of infested plants belonging to these highly susceptible species disorganise the normal functions of the root system, and, as a consequence, there is very serious interference with the flow of soil moisture absorbed by the delicate roots for transference to the leaves and stalks. Very appreciable dwarfing, in the case of susceptible and severely attacked plants, is associated with that disorganisation in the transport of the raw materials required for the building up of plant tissue. Moreover, during hot dry spells such plants wilt much more readily than those that are uninfested. Infested plants of susceptible species are also generally paler in colour than those that have escaped attack, and they have a somewhat sickly yellowish appearance.

Where infestation is heavy and general conditions are favourable to the parasite, the death of the plant may occur much earlier than would normally be the case. The early collapse of the plant may be due entirely to the nematode infestation, but cognisance must also be taken of another factor—namely, the ease with which fungus or bacterial diseases can gain an entrance through the ruptured root tissues. These diseases may be the actual cause of the death of the plant or they may be merely a minor contributory factor.

Extent of Losses.

It would be very difficult indeed to give any estimate of the losses due to the presence of nematode root-gall infestation in Queensland. Local observations suggest that serious reductions in yield have followed in its wake, but no figures are available to indicate just how heavy these losses have been. Elsewhere, however, losses were estimated in some cases, and it is interesting to quote from these estimates. They indicated a loss of 20 per cent. in beans, 12 per cent. in potatoes, 25 per cent. in peas, 13 per cent. in tomatoes, and about 4 per cent. in cotton. Even a loss of 4 per cent. in a highly important crop such as cotton represents a tremendous wastage, if it is a figure that is applicable in most cotton-growing countries and does not represent an abnormally high loss peculiar to the country in which the estimates were made.

Fig. 1

Fig. 2

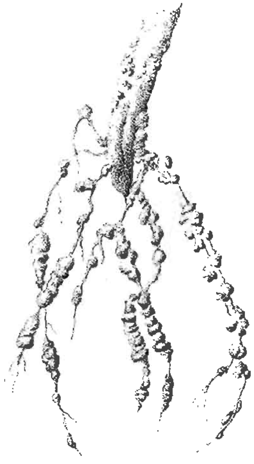


Fig. 3

Fig. 4

Plate 58.—Nematodes.

Fig. 1.—Nematode galls on Strawberry roots.
Fig. 2.—Nematode-infested Potato.
Fig. 3.—Tomato root infested by Nematodes.
Fig. 4.—Bacterial Nodules on roots of Lupin.
(All ½ natural size.)

Organism Responsible for Root Knot.

As already indicated, the malformations characteristic of root knot or nematode root gall are not due to insect attack, but are the direct result of the infestation of the root tissue by a very small eelworm. Eelworms belong to the group of animals called nematodes because of their thread-like appearance. Some of these eelworms are parasitic on plants, others attack animals including man himself, while still others are predaceous on individuals belonging to their own group—i.e., other eelworms. The species associated with root knot is *Heterodera radicicola*, a nematode that has a very wide distribution throughout the world.

Life History of the Root Knot Nematode.

The life history of this species has been worked out in detail elsewhere, but for present purposes the following brief outline is sufficient. The usual male and female sexes occur, and the female is credited with the capacity to lay as many as 500 eggs. The eggs are provided with a tough shell, which serves to protect them against adverse conditions that may occur in the soil. They are extremely minute, being not quite $\frac{1}{250}$ inch in length.

After the usual incubation period, the eggs hatch and a very small thread-like animal emerges. This is the larval stage, and at its commencement the eelworm is about four times as long as the egg from which it hatched. The young larval eelworm moves about freely in the soil until it finds a susceptible plant; having succeeded in doing so, it enters one of the roots, generally choosing a spot near the tip of a young feeding root. A spear-like organ inside the mouth is then used for the purpose of feeding on the fluid contents of the tissue of the root entered by the nematode, and as a reaction to its presence the characteristic swellings are produced at the spot invaded.

In the case of the female eelworm growth is in breadth rather than in length, and eventually the female becomes a pear-shaped or flask-shaped body, which can be detected without the aid of a lens when the infested tissue is broken open and examined. The female nematode is then about $\frac{1}{30}$ inch in breadth, and is a somewhat glistening pear-shaped object. The male also feeds in the root tissue, but it does not attain the flask-shaped form of the female; on the contrary, it remains long and worm-like. The various stages in eelworm development are illustrated in Plate 57, figs. 3, 4, 5, 6.

Figures are not available to indicate how many generations are passed through in Queensland in the course of twelve months, but, as twelve generations are possible in the Southern United States, there is every reason to believe that in Queensland at least a similar number of generations occur.

Conditions Favouring Infestation.

Nematode infestation is generally at its maximum in light sandy soils in semi-tropical or tropical regions. The relatively slight variations occurring in the temperature in such areas permit of almost uninterrupted development, and the texture of the soils in question is also highly conducive to the excessive multiplication of soil-infesting nematodes.

Heavy soils are generally much less susceptible to infestation, probably on account of the difficulty experienced by the nematodes in moving from plant to plant in such soils. Where soils are subjected to repeated flooding and are normally very wet, infestation is slight; on the other hand, if the soil is abnormally dry, infestation is also unimportant.

Means of Dissemination.

It is generally believed that the larval nematodes move through the soil at the rate of only a few feet each year. Such being the case, there must be some means of dissemination other than the mere haphazard wandering of the larval nematodes in search of the roots of susceptible plants.

Seedlings or nursery stock infested with nematodes have frequently been the means of establishing the pest in areas previously free from its ravages. Seed potatoes have been similarly responsible for nematode dissemination, while manure containing portions of the roots of infested plants has also been a factor in their spread.

The rapid dissemination of this pest has been facilitated by the ordinary operations of cultivation, for implements used in infested paddocks can transfer the nematodes to uninfested paddocks through the agency of the soil adhering to their various parts. They may similarly be transported in the soil adhering to the boots of workers or to the hoofs of animals. Drainage, irrigation, or other running water may also serve as a means by which the parasite can be transported.

Susceptible Plants.

The number of species of plants recorded as being attacked by the root-knot nematode is now extremely large and is frequently being added to. Many of the most important plants cultivated by man for his own sustenance are included in the category of susceptible plants, and mention may also be made of the fact that many weeds are attacked.

Asparagus, banana, bean, beet, carrot, celery, cotton, cucumber, fig, grape-vine, lettuce, onion, papaw, pea, peach, pineapple, potato, pumpkin, strawberry, sugar-beet, sugar-cane, sweet potato, tomato, and water-melon may be mentioned as some of the more important plants subject to severe attack.

Fig. 1

Fig. 2

Fig. 3

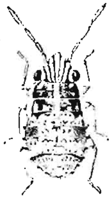


Fig. 4

Fig. 5

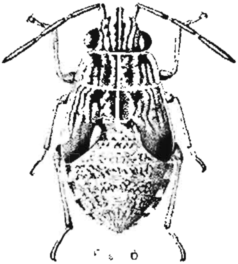


Fig. 6

PLATE 59.—THE RUTHERGLEN BUG (*Nysius sp.*).

Fig. 1.—Egg × 18.
Fig. 2.—1st nymphal stage × 20.
Fig. 3.—2nd nymphal stage × 20.
Fig. 4.—3rd nymphal stage × 20.
Fig. 5.—4th nymphal stage × 20.
Fig. 6.—5th nymphal stage × 20.

PLANTS RESISTANT TO ATTACK.

Among the plants that are immune to attack or but slightly affected, mention may be made of barley, broom millet, four varieties of cowpea (Brabham, Iron, Monetta, and Victor), grasses (most), maize, peanut, sorghum, wheat, and velvet beans.

CONTROL MEASURES.

It will be evident from what has already been written on this subject that the control of the root-knot nematode parasitic on economic plants must of necessity present a very difficult problem. Here the farmer, fruitgrower, or nurseryman is dealing with a parasite that is for most of its lifetime entrenched within the living root tissues of the plant to be treated or protected. When not in the plant tissues it is free in the soil, where it frequently occurs in enormous numbers. Further complications are caused by the fact that there are many weeds on which it can exist even if the land is cleared of susceptible cultivated plants.

It may be definitely stated that the cure of infested plants is quite outside the bounds of practicability, and hence control should aim at eliminating or reducing the numbers of nematodes inhabiting the soil where land is already infested. Where it is uninfested, every effort should be made to maintain it in that happy condition.

Nursery stock or seedlings showing any symptoms of root knot should not be planted on uninfested lands, and, indeed, such stock or seedlings are undesirable for planting even on infested lands. Care should also be taken to avoid the use of infested seed potatoes. Mention has already been made of the possibility of infestation by implements, live stock, running water, &c., and accordingly all practicable precautions to eliminate such sources of infestation should be taken. If these precautions are observed, uninfested land may be kept free of this very serious pest.

The fact that quite a number of valuable crops are immune or highly resistant to attack has been used to reduce infestation by means of rotation; a rotation being adopted in which these immune crops feature prominently. The immune or resistant crops were referred to in an earlier paragraph, and consideration might be given to the growth of certain of these crops where it is desired to reduce nematode infestation in order to permit of the subsequent growth of susceptible crops. The actual crop selected for the rotation would, of course, depend on many factors that cannot be entered into in these notes.

Infested greenhouses or seed-beds can be treated by methods that would be much too expensive on a field scale, and in this connection mention may be made of the fact that steam sterilisation of the soil in greenhouses is regularly carried out in many large establishments throughout the world. In cases where sterilisation is desired but steam is not available, much good may be effected by treating pots or other

containers and their soil contents with boiling water at the rate of five gallons per cubic foot. After treatment, several days should be allowed to elapse before planting, in order to permit of the soil draining in a thoroughly satisfactory manner.

Even where infestation is present, susceptible plants may sometimes be kept on quite a profitable basis by a judicious combination of thorough cultivation and heavy manuring.

During recent years much experimental work has been devoted to an endeavour to control nematodes on a field scale by soil fumigation. However, so far as Queensland conditions are concerned, no data are yet available to show that such is both economically practicable and effective.

The Rutherglen Bug.

The notorious sucking insect known as the Rutherglen bug (*Nysius sp.*) may be found in small numbers every year in Queensland, but it is only in certain seasons that it reaches epidemic proportions, and in these it can justifiably be regarded as one of the most destructive Australian insects. Such an epidemic occurred during the months of October, November, and December 1926. That epidemic subsequently died down as suddenly as it commenced, and since the date mentioned no records of the occurrence of Rutherglen bug, except as isolated individuals, have been obtained. Doubtless it will sooner or later reappear as a very serious pest for a comparatively brief period.

The Rutherglen bug belongs to the family Lygæidæ, and is thus allied to some notorious pests among which are the chinch bug of the United States, which is generally regarded as being one of the most destructive insects of that country.

Feeding Habits and Nature of Injury.

The feeding habits of the Rutherglen bug are typical of the order to which it belongs, in that it pierces the skin or epidermis of the leaf, stalk, or fruit on which it is feeding, and through the punctures thus formed it sucks up the plant sap. The type of mouth parts modified to permit of feeding in this manner is illustrated in fig. 7B, Plate 60.

The damage caused by each individual bug is quite trivial, but in an epidemic the numbers feeding in an infested orchard or field are so great that there is a tremendous loss of sap in the attacked plants. When field crops are attacked the leaves wilt and frequently die, and the yield of the crop is thus seriously reduced, and in extreme cases the crop may be a total failure. When an outbreak is in an orchard many of the young attacked fruits fall to the ground, and of those that still remain on the trees a large proportion are blemished.

Among plants attacked by this pest are the following:—Potato, tomato, beetroot, cabbage, citrus, peach, plum, apricot, cherry, mango, grape-vine, and cotton.

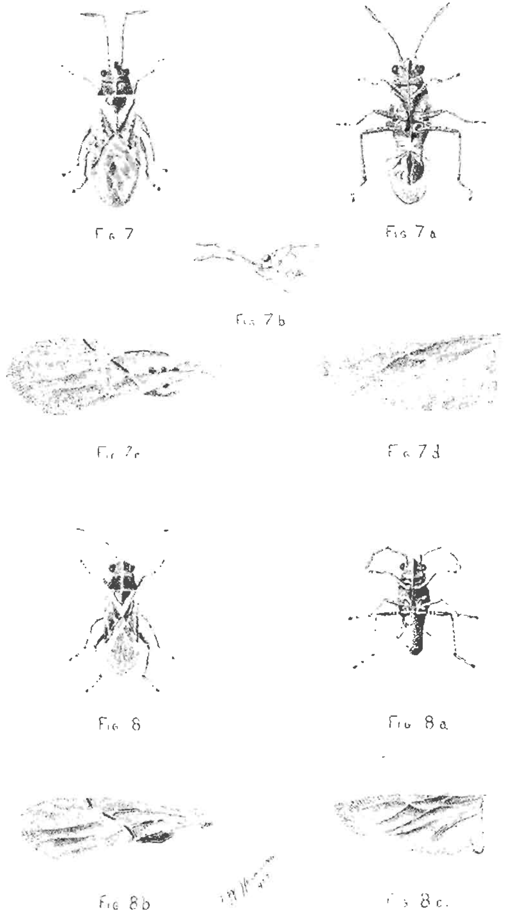


PLATE 60.—THE RUTHERGLEN BUG (*Nysius sp.*).

Fig. 7.—Adult female, dorsal view, x 6.
Fig. 7*a*.—Adult female, ventral view, x 6.
Fig. 7*b*.—Adult head and mouth parts, lateral view, x 6.
Fig. 7*c*.—Forewing, female, x 12.
Fig. 7*d*.—Hindwing, female, x 12.
Fig. 8.—Adult male, dorsal view, x 6.
Fig. 8*a*.—Adult male, ventral view, x 6.
Fig. 8*b*.—Forewing, male, x 12.
Fig. 8*c*.—Hindwing, male, x 12.

Life Cycle Stages and Life History.

Until recently little had been published with respect to the life history of this very important Queensland insect, but, as a result of work carried out in 1926 by J. Harold Smith, it is now possible to give an outline of the more important details of its life-history and life-cycle stages.

The first stage in the life cycle of this species is the egg. (Plate 59, fig. 1.) Eggs have been found on sow thistle (*Sonchus oleraceus*), cudweed (*Gnaphalium purpureum*), and blady grass (*Imperata arundinacea*). On the first-mentioned plant the eggs are laid in bundles of from two to seven on the pappus of the flower-head, on the second they generally occur singly in the fine down that is characteristic of cudweed, while on the blady grass they are found singly on the seeds. The newly laid eggs are creamy white in colour, elongate oval in shape, and measure one millimetre in length, the maximum diameter of the egg being about a quarter of its length. As the incubation period advances, the egg colours up very characteristically, and hatches on an average in six days during the spring months. The greatest number of eggs laid by one female in the laboratory investigations already referred to was 435.

The egg stage is succeeded by the nymphal stage, in which the insect feeds actively, moults five times, and produces the winged adult at the fifth moult. Extensive observations made during the epidemic of 1926 showed that under the conditions then prevailing the nymphal stage lasted for about three weeks, which, when added to the incubation period of six days, means that just on four weeks elapse from the laying of the egg to the appearance of the winged adult or imago.

Descriptions of the various nymphal instars are hardly necessary in these notes; they are well illustrated in Plate 59.

The adult (Plate 60) is a small active insect measuring slightly more than $\frac{1}{8}$ inch in length. It is of a somewhat dull greyish-brown colour, and possesses two pairs of gauzy silvery-grey wings that are folded on its back. During the daytime it moves about rather actively, and readily takes to the wing when disturbed, but in the early morning and evening it is much less active.

Control.

With regard to control, it must be admitted that this pest is by no means an easy one to handle, and further field investigations are necessary before the position can be regarded as being at all satisfactory. Nicotine sulphate and kerosene emulsion have been used as sprays, but for various reasons these sprays cannot be regarded as offering a satisfactory solution of the problem of control. Spraying with such poisons as arsenicals should not be employed against this pest, because it does not eat the foliage on which it is feeding, but merely punctures the skin or epidermis and sucks out the sap without eating the tissue that has been poisoned by the arsenical spray.

Some experimenters believe that the most hopeful line of attack, if the area to be treated is not too extensive, is to use some mechanical means by which the bugs can be collected in large numbers. In New South Wales an endeavour has been made to do so by using sheets of galvanised iron, the sides of which are turned up slightly to form shallow containers, into which is poured a mixture of kerosene and water in the proportion of one pint of kerosene to one gallon of water. These containers are placed under the branches of the trees in the very early morning, and the branches are then jarred sharply, when it will be found that numbers of the torpid bugs fall into the kerosene and water and are killed. If sheets of iron are not available, or are regarded as too expensive, any large sheets of canvas or other material can be spread beneath the trees, and when the bugs have been jarred on to these sheets they can be gathered up and the bugs shaken into a kerosene tin containing kerosene and water.

Where field crops have to be treated it may be possible to exercise a certain measure of control by using a modification of this method by drawing shallow containers between the rows and beating the plants on either side to drive the bugs into these containers.

During the epidemic of 1926 various insecticides were tested out in South-eastern Queensland, and in certain preliminary trials nicotine dusts gave promising results. It is hoped that it will be possible to further test out these promising insecticides when the next epidemic occurs.

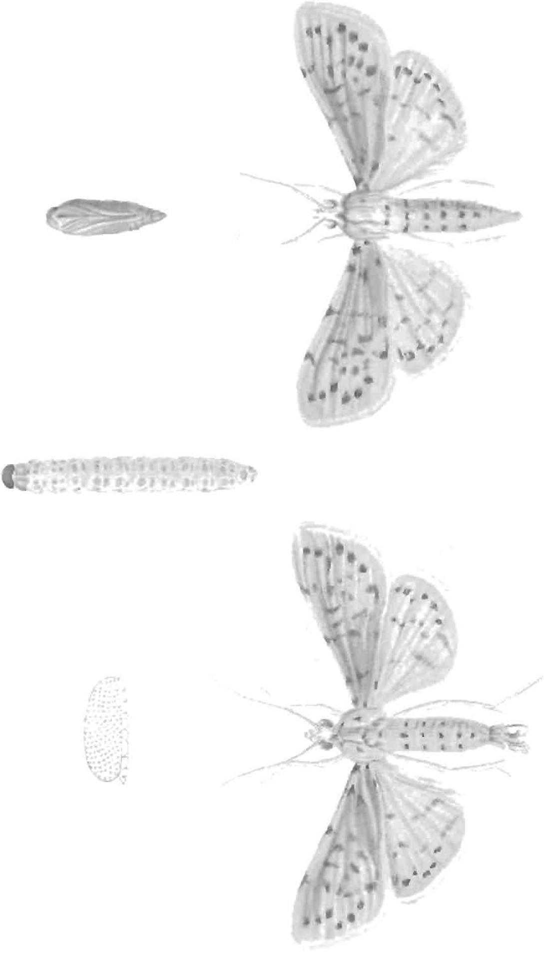
One grave difficulty experienced in handling this pest is due to the fact that during an epidemic the Rutherglen bug is breeding in enormous numbers in uncultivated areas, and even if an orchard or a field crop is satisfactorily cleaned up one week there is no guarantee that it will not be just as heavily infested next week by migration from uncultivated areas.

It will be realised from what has been said that there is as yet no easy, effective, and practicable means of handling this serious native pest, and it must be included in the category of those that require much further investigation.

The Yellow Peach Moth.

The yellow peach moth (*Dichocrocis punctiferalis* Gn.) is a pest of a wide range of economic plants. As its common name indicates, it attacks peaches, but it is also an important enemy of maize, cotton, papaws, custard apples, loquats, and oranges. In the case of maize infestation the cobs and stalks are attacked. The papaw is attacked in both the fruit and the stem, while in the case of the cotton plant the bolls are often seriously infested. The fruit is attacked in the case of the orange, custard apple, and loquat.

The moth is a very pretty little insect with orange-yellow wings conspicuously marked with a considerable number of black spots (Plate 61, figs. 4, 5). It has a wing-spread of about 1 inch.



The full-grown grub (Plate 61, fig. 2) is of a light greyish white colour broken by a number of much darker spots, and is frequently suffused with pink. The pupa is of the usual type (Plate 61, fig. 3), and the egg is as illustrated (Plate 61, fig. 1), these two stages requiring no special comment.

The control of this pest is a difficult problem, but some measure of relief may be obtained in orchards by eliminating alternative host plants of little commercial value. Spraying with arsenate of lead may also be productive of good results by killing some of the young larvæ. The cleaning up and destruction of waste material that may harbour this pest is also worthy of consideration as a helpful control measure.

Armillaria Root Rot.

Armillaria mellea, commonly known as the honey fungus on account of the characteristic colour of its mushroom-like fruiting stage, is one of the comparatively few fungi which are well able to adapt themselves to either a saprophytic or parasitic habit of growth. Normally this fungus lives as a saprophyte on old decaying roots, stumps, &c., but should it come in contact with the root of a suitable living host it can attack this, usually per medium of some injury, and cause extensive rot which very often ends in death.

As a parasite the fungus is capable of attacking many different hosts belonging to widely separated groups of plants. In Europe, considerable loss occurs in the pine forests as the result of the rotting of the roots and base of the trunk by this fungus. In America many native and introduced trees may be attacked. In Australia Armillaria root rot is found affecting, in many cases to a serious extent, citrus, deciduous trees, especially the apple, and the grape. The potato is also sometimes attacked, and is noteworthy as being one of the few herbaceous plants affected with the disease.

Symptoms.

Unfortunately this rot is a somewhat insidious disease, and considerable damage may be done to the underground parts of the plant before the symptoms resulting from this are sufficiently marked to be noted. An affected tree usually exhibits a stunted condition of growth, a yellowing of the foliage, and possibly more or less dieback. Branches on one side having for their source of supply one or more attacked roots may exhibit these symptoms to a more marked extent. Frequently the tree when approaching a dying condition will throw an abnormally large crop of fruit as a last effort to perpetuate its species.

Should any such symptoms be observed, the soil should be removed well away from all the main roots and a careful examination made for signs of Armillaria invasion. This will be indicated by more or less extensive areas of soft rotting bark, which may be easily stripped off, and yields a characteristic mushroom odour. White felt-like wefts of closely interwoven fungal threads may sometimes be observed lying between the bark and the wood.

The most characteristic feature is the presence of shiny-black or dark-brown string-like fungal strands or rhizomorphs. These rhizomorphs are specially modified structures developed to enable the fungus to resist the adverse conditions of desiccation, &c., met with during its life in the soil. Each strand consists of an outer resistant layer or cortex formed of closely interwoven fungal threads or mycelium, which are intimately fused with one another to give a cellular structure resembling that found in the higher plants. The central portion consists of more loosely woven mycelium, and is known as the medulla. The section of the sclerotium of *S. rolfsii* illustrated in Plate 3, fig. 2, shows a similar type of structure.

In citrus the black rhizomorphs lie more or less embedded in the softened bark or else radiate out as free, branched strands. In the former case they may appear merely as short black irregular streaks protruding from a crack in the bark, or they may be entirely superficial though firmly attached (Plate 62).

In the apple and most other fruit trees the rhizomorphs are free and appear as black strings more or less tangled round the roots. These are attached at various points, and from these the fungus extends out into the bark and woody tissue of the plant.

The rhizomorphs are capable of growth from their free ends for considerable distances through the soil, and it is largely by this means that the spread of Armillaria takes place.

Armillaria mellea belongs to one of the highest groups of fungi, the Agaricaceæ, which includes those of the mushroom type. During a period of wet weather in the autumn the fruiting bodies of this fungus may appear in clusters round the base of old rotting stumps, &c., or beneath fruit-trees badly affected with the disease. These structures are of the ordinary toadstool shape, and have a yellow-brown or honey-coloured stalk and disc, the latter being speckled over with small brown scales. The gills on the under surface of the disc are white and distinct. Covering the outside of each gill is the layer known as the hymenium. This consists of closely packed club-shaped cells, some of which project somewhat further than their neighbours and develop on their apex four short peg-like projections, on each of which is developed a minute rounded basidiospore. (Plate 5, fig. 6, illustrates the type.) Many millions of these spores may be produced in a day by one toadstool.

The basidiospores germinate and are able to infect decaying wood with which they may be associated and thus serve to extend the saprophytic activities of the fungus. Apparently the living plant becomes infected only when attacked by one of the rhizomorphs. In a new orchard these have been previously developed upon rotting remains of scrub and forest trees left in the ground during clearing operations. Usually the fungus gains entrance through an injured or dying root or through one which is closely associated with the original rotting material.

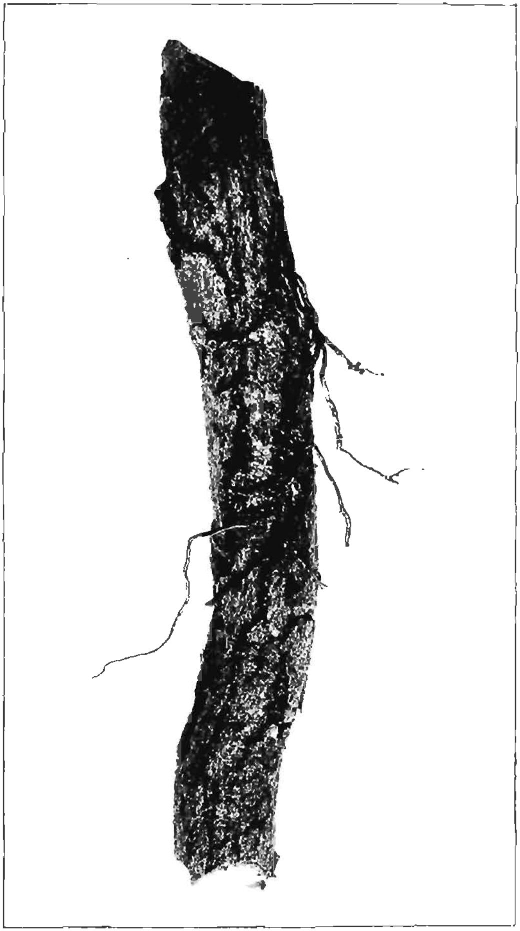


PLATE 62. ORANGE ROOT ATTACKED BY *Armillaria mellea*.

Control.

If possible, land which is to be used for orchard purposes should be well stumped and have all the main roots removed by thorough and deep ploughing. Annual crops, other than potatoes which are also affected, could be planted for a year or more in order to allow time for the fungus to die out of the soil.

If a preliminary inspection has shown a tree to be attacked, the soil must be removed well away from the crown and main roots so as to expose them to easy access. Any badly rotted roots are then removed entirely. Others less extensively attacked must have the affected areas thoroughly cut out until sound tissue is reached, after which Bordeaux paste should be painted on the wounds. Any diseased material will of course be carefully collected and burnt. The pieces may be conveniently gathered by laying a piece of paper under the scene of operations. The main roots should be left exposed to the beneficial action of the sun and air for as long as the absence of frosts will permit. This treatment is usually effective only if the disease is caught in its early stages before the fungus has penetrated too deeply into the wood.

If a tree is too badly diseased for remedial measures to be a success, it should be carefully removed together with all its roots, and should be burnt on the spot. If the original stump or root from which infection started can be located, this also should be dug out and burnt.

The affected area is then best isolated, to prevent the spreading of the fungal rhizomorphs through the soil to healthy trees, by digging a trench 2 feet deep round the outside of the furthest root extension of the diseased one. The soil within the trench should be repeatedly turned over and exposed to the sun. Replanting should be delayed for two or three years, otherwise there is a chance for the new tree to become infected from rhizomorphs unintentionally left in the ground.

Sclerotium Crown Rots.

The fungus *Sclerotium rolfsii* is a soil-inhabiting plant parasite found widely distributed throughout the world. It shows very little discrimination as regards its selection of a host, and, so long as the conditions are such that abundance of warmth and moisture are provided for, it would appear capable of attacking a wide range of herbaceous plants. A few of the cultivated plants recorded in other countries as being attacked by the parasite are tomato, potato, tobacco, rhubarb, cotton, peanut, maize, citrus, strawberry, bean, carnation, violet, chrysanthemum. Acting as a storage rot, it may attack cucurbits, cabbage, and Irish and sweet potatoes. In Queensland *S. rolfsii* has appeared chiefly in commercial and private flower gardens, attacking delphiniums, carnations, and gerberas. It has also caused loss in some economic plants, including the strawberry, orange, and persimmon.

Symptoms.

The fungus usually attacks its host at the crown just below ground-level. The outer tissues are invaded and a rot set up which may encircle the stem and spread down along the roots. The presence of disease then becomes manifested in a wilting of the upper portion of the plant. If the weather conditions are moist, the mycelial threads of the fungus will grow out together in a longitudinal direction to form white radiating fans which extend up the stem and outwards over the surface of the soil. Often there is associated with the white threads a number of small rounded brown bodies known as sclerotia (Plate 63).

In the case of the strawberry, the white mould growth can be seen amongst the bracts and leaf débris of the crown, and from here the radiating fungal threads extend out along the base of the leaf and fruit stalks, which soon assume a brown rotten condition, with the result that the leaves and fruit wilt off and die.

The orange and persimmon are affected in the seed-bed. At one or several points in the bed the seedlings commence to wilt off, and the trouble continues to spread in an ever-widening circle. On pulling up a wilted plant, the stem is seen to exhibit just below ground-level a dark shrunken area of decay associated with which is the fungus.

The Causal Organism.

Sclerotium rolfsii is one of the few fungi which have never been known to develop a definite reproductive stage. For this reason it is included for convenience with several similar types in the group *Mycelia-Sterilia.*

The fungus is distributed by means of mycelial threads and sclerotia which are carried about in association with the remains of the host plant or in infested soil. The sclerotia are structures specially adapted to resist desiccation and other adverse conditions of their environment, and so serve to a certain extent the purpose of the spore of other fungi in the perpetuation of the disease.

In the formation of these sclerotia the fungal threads become aggregated at certain points, and branch and rebranch to give many short segments or hyphæ, which become interwoven to form a loose white cottony ball of somewhat less than $\frac{1}{8}$ inch in diameter. By further branching, interweaving, and fusion of the hyphæ a firmer structure is produced. This becomes differentiated into an outer firm, resistant layer or cortex in which the individual threads have become so fused together as to form a cellular structure somewhat resembling the parenchymatous tissue of higher plants. The interior or medulla consists of thinner walled hyphæ arranged in a somewhat looser manner. (Plate 3, fig. 2.) As the sclerotium matures its colour changes from white to light or dark brown, and finally takes the form of a firm rounded body of about $\frac{1}{10}$ inch or less in diameter, somewhat resembling in appearance a small round radish-seed.

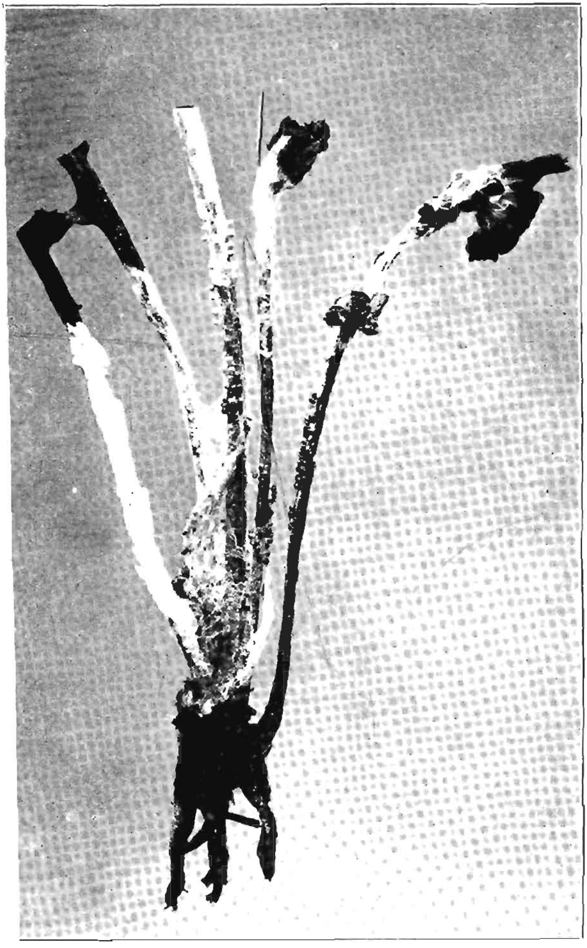


PLATE 63.—GERBERA ATTACKED BY *Sclerotium rolfsii*.

Control.

The soil-frequenting habits of this fungus make its effective control a somewhat difficult problem.

1. Pull out and burn any diseased plants.

2. Do whatever may be possible, by means of thinning out and pruning, to allow access of sun and air to the plants, as it is moist conditions that are specially conducive to the growth of this fungus. Good drainage and wide spacing of the plants will help in this direction.

3. To eliminate the fungus from the soil after it has become infected is a difficult matter. Taubenhaus in America has shown that the mycelium and sclerotia are apparently killed when buried more than 5 inches deep, and hence deep ploughing or digging-in of affected soil may be beneficial. Drenching the ground with lime sulphur solution may be useful in checking the disease in the seed-bed, while the same mixture sprayed well into the crown of strawberry plants may prove of use when this plant is attacked.

CHAPTER XIV.

DIRECTIONS FOR ENTOMOLOGICAL AND PATHOLOGICAL INQUIRIES.

The Department of Agriculture and Stock receives a considerable volume of correspondence asking for advice as to the most satisfactory means of dealing with various pests and diseases, and the officers of the department are always prepared to immediately supply whatever information is available. It unfortunately happens, however, that in many cases no specimens accompany the inquiry, and, in addition to the absence of specimens, the information supplied by the inquirer as to the nature of the damage is often very meagre. It thus follows that frequently no definite advice can be tendered until specimens and fuller details have been obtained by further correspondence. Such delay only too frequently means that, by the time the advice is received by the inquirer, the infestation has reached such a stage that the recommendations made are too late to be of much value in checking the particular outbreak forming the subject of the inquiry. These recommendations will, however, always be of value for immediate application should there be any recurrence of the trouble. For the reasons just enumerated, it is necessary to impress upon every inquirer the desirability of furnishing specimens, accompanied by full details as to the nature, extent, and duration of the outbreak. Furthermore, stress must be laid upon the necessity for communicating with the Department of Agriculture and Stock when the attack is in its early stages, for delay usually adds to the difficulties of effective control.

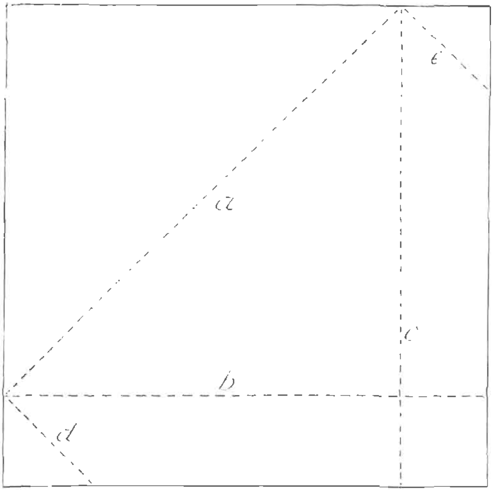
Entomological Inquiries.

The following information is supplied to ensure the receipt of insect specimens in a condition suitable for satisfactory examination and identification:—

1. Insect specimens should never be forwarded in envelopes, because if they are at all soft-bodied—e.g., fruit flies or aphis—they are generally so squashed in transit as to be of little value for specific identification, while the small harder-bodied insects frequently lose legs or heads in transit in envelopes.

2. Soft-bodied insects, such as aphis and thrips, are best forwarded in a small tube containing alcohol or methylated spirits, the tube being packed in sawdust or cotton wool in a tin matchbox or tobacco tin or similar container.

3. Small hard-bodied insects, such as beetles and wasps, are best packed in a tin matchbox; a little cotton wool, or failing that some small pieces of newspaper, used as packing inside the box will serve to prevent



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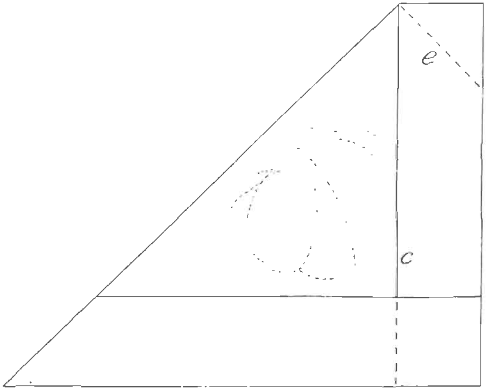

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PLATE 64.
Paper Containers for forwarding Moths and Butterflies.

the insects becoming damaged through undue movement in transit. A drop or two of carbolic acid in the container before packing is of some value in preventing mould, and it also acts as a deterrent to the attacks of other insects—e.g., ants.

4. Ticks, fleas, mites, and lice can be forwarded in spirit or alcohol in tubes.

5. Butterflies and moths should be killed as carefully as possible and placed in paper triangles made as follows:—Fold along line *a* as shown in fig. 1, Plate 64, then along line *b*, then along line *d*; this forms a container (shown in fig. 2) into which the dead butterfly or moth can be slipped after its wings have been carefully folded in such a manner as to prevent the scales of the wings being rubbed off. The triangle can then be closed by folding along the line *c* and folding along *e*. Place only one butterfly or moth in each triangle. The paper triangles can be packed in a tin and forwarded in the usual manner.

6. If the insects are in the caterpillar or grub stage and are alive, place a small quantity of their food plant in the package so that the insects will remain alive until received at the Department of Agriculture and Stock, but pack the food so that it will not move about unduly and thus injure the caterpillars or grubs.

7. If the insect has pupated, place it in a tin in which its movements are reduced to a minimum by the judicious use of cotton wool or torn-up pieces of paper.

8. If the inquirer is forwarding insect-infested fruit he should on no account send it in closely sealed tins, because, as a rule, the consignments so forwarded reach the department in such a fermented condition that the insects they contain are invariably killed by the fermentation generated in such a container; such fruit should be packed in wood-wool or straw in a well-aired container.

9. Large insects, such as grasshoppers, should have their abdominal contents removed before being packed in a mailing tin.

10. Where plant bugs are being forwarded it is always important to send the fully mature winged forms, because the identification of the immature wingless forms is a difficult and in many cases an impossible task: in all inquiries it is desirable that the inquirer should forward as many stages in the insect's life cycle as can be conveniently obtained.

11. Insects are best killed in a "killing bottle," which consists of an ordinary strong bottle with a layer of plaster of paris and potassium cyanide at the bottom; when this is tightly corked it becomes so charged with hydrocyanic acid gas, generated by the potassium cyanide, that a few minutes in the bottle generally suffices to kill most insect life.

12. Where a cyanide "killing bottle" is not available a drop or two of chloroform will be found effective in killing many insects.

Specimens of the damage should be forwarded with the insects when the inquiry is made, but it is necessary to send only the portion of the plant that is attacked—e.g., the fruit, or leaf, or root, or stalk, as the case may be.

The details to be supplied by the inquirer will naturally vary, but as a rule the following should be included:—(1) Date of insect outbreak; (2) degree of severity of attack; (3) area attacked; (4) crop attacked; (5) age of crop; (6) general health of crop apart from the insect attack; (7) nature of soil and drainage; (8) nature of surroundings—e.g., is the farm or orchard isolated in uncultivated land or in scrub, or is it adjacent to other farms or orchards; (9) measures, if any, already taken to cope with the pest.

The forwarding of specimens and details has been dealt with at some length, because it is felt that the outcome of many inquiries will be of a much more satisfactory nature if greater attention is paid to the forwarding of specimens and full details when the inquiry is originally made.

Pathological Inquiries.

Of the many specimens submitted for report a considerable number are found on opening up to be more or less unfit for enabling a proper determination of the cause of the trouble. This position usually arises from one or more of the three following causes:—

1. The specimens have rotted during transit and are unfit for examination.
2. The portion of the plant in which the causal agent might be found is not included.
3. There is not sufficient data given regarding the general growing conditions of the plant, in which conditions, in many cases, is found the origin of the trouble.

To aid those desirous of seeking advice, a few hints regarding the submission of specimens are given below:—

The method of packing will depend largely on the nature of the specimen and the time that it will take on its journey.

When the parcel may be expected to reach its destination in not longer than two days, the specimens, whether of foliage or fruit, can be wrapped separately in clean newspaper and packed in a cardboard box to avoid crushing. An airtight container must be avoided, as the material sweats and quickly rots under such conditions.

For long-distance consignment, foliage is best pressed between sheets of blotting paper, which can be posted enclosed between two pieces of cardboard. When wishing to send succulent fruit, such as are liable to arrive in a state of decomposition, it is sometimes possible to cut off the diseased portion in a thin layer and send this wrapped in clean blotting paper as in the case of foliage.

When possible, specimens illustrating the disease in all stages, including both early and late symptoms, should be sent.

If the disease consists of a definite leaf or fruit spot, only that portion of the plant affected need be included. However, in the case of diseases of a more general nature, such as a wilt or dieback, it is necessary to forward specimens of the whole plant, including especially the roots. It is always best to include whole specimens when dealing with small herbaceous plants or seedlings.

A covering letter should be sent indicating the date on which the specimens were posted, and stating the nature of the information required. As far as possible, the following details should be included also, to facilitate a correct diagnosis of the trouble:—

(*a*) A short description of the disease as it appears in the field; the varieties of plant affected; the date of first appearance; and nature of subsequent spread, &c.

(*b*) Nature of the soil and subsoil and drainage; details of any manurial application; and date of application.

(*c*) Particulars regarding rainfall, frosts, &c., occurring during the life of the crop.

(*d*) The strength and time of application of any sprays used.

(*e*) Any contributing cause which might suggest itself to the grower.

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